

**EVALUATING THE USE OF ALUM SLUDGE IN THE TREATMENT OF WASTEWATER
EFFLUENT FROM NAMATAALA WASTEWATER STABILISATION PONDS-MBALE**

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ABSTRACT

This research focuses on the evaluation of the use of alum sludge from the Manafwa water treatment plant, which is cost-effective and environmentally friendly for treating wastewater effluent from WWSPs. The case study was done on Namataala wwsp in mbale city with discharges of 24499.98m³/day of wastewater into Namataala wetland, which contains high levels of BOD, COD, and nutrients.

The values of the parameters of the sampling point or discharge point were above the permissible limits: a COD of 235.67±14.01 mg/l, a BOD of 192.02±1.53 mg/l, total nitrogen of 49.7±4.51 mg/l, and total phosphorous of 30.6±0.21 mg/l.

Alum sludge from water treatment plants is a readily available material obtained as a result of using aluminum sulphate as a primary coagulant in water treatment. From this research, alum sludge showed potential to produce an alum sludge extract that was used in the coagulation process in wastewater treatment.

The parameters of interest we based them on were BOD, COD, TN, and TP. After taking wastewater through the coagulation process, which was followed by sedimentation, alum sludge extract showed a percentage reduction of BOD-79.9%, COD-79.7%, TN-87.7% and TP-92.2%. Therefore, alum sludge has a potential to be used in treatment of wastewater.

DECLARATION

I, NUWABIINE YASSIN, with registration number S20B32/266, declare that the work provided here is authentic, that it is the result of my own efforts, and that it has never been submitted to any university for any award.

Signature:

Date:

APPROVAL

In witness whereof, the report compiles the research for the use of alum sludge in the treatment of wastewater effluent in the case study of Namatala wastewater stabilization ponds in mbale and is compiled by Nuwabiine YASSIN under the supervision of the project supervisor;

Project Supervisor

MR. GAVA JOB SSAZI PIUS

Signature:

DEDICATION

I dedicate this report to my **guardians, Mr. & Mrs. Muganzi David** for their tireless effort they have placed in my education, comfort and support.

ACKNOWLEDGEMENT

I am grateful for the support from many individuals. With the financial assistance of my guardian, Kyatuhaire Rabecca, my heartfelt gratitude goes to you for your strictness in educational things. My gratitude also extends to all other family members for their emotional and spiritual support, prayers, and encouragement in completing this project. Mr. Gava Job Ssazi Pius, who assisted me academically and served as my supervisor, deserves my heartfelt gratitude. Thank you very much. My project partner, Ms. Alungat Susan, has also been really helpful and supportive.

May the Almighty God reward you All abundantly.

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LIST OF ACRONYMS

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
NEMA	National Environmental Management Authority
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
WSPs	Waste Stabilization Ponds
EC	Electric Conductivity
AAS	Atomic Absorption Spectroscopy
DF	Dilution factor
FWS	Free Water Surface
SSF	Subsurface Flow systems
PAC	poly aluminum chloride
PFC	poly ferric chloride
PFS	poly ferrous sulphate
TP	Total Phosphorous
TN	Total Nitrogen

CHAPTER ONE

1.1 INTRODUCTION AND BACKGROUND

Namatala Wetland is a papyrus wetland located in the Eastern Region of Uganda, in Mbale city (Zsuffa, van Dam and Kaggwa, no date). It is a vital ecosystem that provides a variety of important services, including water filtration, flood control, and habitat for biodiversity (Mitsch *et al.*, 2009). The wetland is fed by the Namatala River and a number of smaller streams. It covers an area of approximately 3,000 hectares and is home to a variety of plant and animal life, including papyrus, reeds, sedges, birds, fish, amphibians, and reptiles (Datta *et al.*, 2022).

Wastewater treatment is the process of removing impurities from waste water to fulfill effluent discharge criteria (Droste and Gehr, 2018). The goal of waste water treatment is to eliminate or minimize organic and inorganic chemicals, nutrients, poisonous compounds, and kill pathogenic organisms (Kuo and Smith, 1997).

However, Namatala Wetland has been affected by effluent from Namatala treatment ponds. The treatment ponds are designed to remove pollutants from wastewater before it is discharged into the wetland. However, the treatment ponds are not always effective in removing all pollutants. As a result, the effluent from the treatment ponds can contain high levels of nutrients, suspended solids, and other pollutants (Namaalwa *et al.*, 2020). The discharge of effluent from the treatment ponds into Namatala Wetland has a number of negative impacts. The nutrients in the effluent can lead to eutrophication, which is a process that causes excessive algae growth. Eutrophication can reduce the amount of oxygen in the water, which can kill fish and other aquatic life. The suspended solids in the effluent can also clog the gills of fish and other aquatic life.

In addition, the effluent from the treatment ponds can contain pathogens, such as bacteria and viruses. These pathogens can cause diseases in humans and animals (Namaalwa *et al.*, 2020).

The Namatala waste treatment plant has two aerobic ponds, 4.6m and 3.96m deep, with the purpose of facilitating the growth and activity of aerobic microorganisms responsible for the breakdown of organic substances in wastewater (Namaalwa *et al.*, 2020). This facultative pond is of depth 3.35 m, and the top zone of this pond is aerobic, while the lower zone is anaerobic. This pond allows for the reduction of biological oxygen demand (BOD) and the further removal of organic matter (Verbyla and Mihelcic, 2015). The amount of oxygen present in this pond depends on temperature, organic loading, and sunlight. And in the maturative pond of depth 2.743m, the effluent from the facultative pond is received, and additional sedimentation occurs, allowing any residual solids to settle at the pond's bottom (Verbyla and Mihelcic, 2015).

Alum sludge is a product formed as a result of the water treatment operations, which include coagulation, flocculation, clarifying, and filtering, followed by dewatering procedures in the treatment of raw water with aluminium sulphate as a primary coagulant (Zhao *et al.*, 2021b). The volume of Alum sludge has expanded globally in recent years due to the growing demand for clean water brought on by the world's population growth and urbanization. Therefore, there is a great deal of anxiety about how to handle Alum sludge effectively and efficiently in order to save money when it comes time to dispose of it while preserving environmental sustainability (Zhao *et al.*, 2021a).

1.2 PROBLEM STATEMENT

There is degradation of the Namatala natural wetland through pollution by wastewater effluent from Namatala and Doko waste stabilization ponds (WSPs) in Mbale. The effluent from the ponds and urban streams is the main source of nitrogen, phosphorus, BOD, and COD in the wetland (Namaalwa *et al.*, 2020). The waste stabilization pond systems were originally constructed for a population of around 45,000 (AWE, 2018), with Mbale municipality having a population of around 100,000 inhabitants (UBOS, 2014). The stabilization ponds use bacterial activity to remove organic matter, nutrients, and microbes from the sewage, with a design capacity of 372.6 m³ (NWSC, 2023). Therefore, partial treatment of sewage is done, and thus effluent discharged into the wetland is above the standards of the National Management Authority (NEMA), where a COD of 235.67 mg/l, a BOD of 192.02 mg/l, total nitrogen of 49.7 mg/l, and total phosphorous of 30.6 mg/l (YASSIN. N, 2023) are discharged to the wetland, which are above the standards for effluent wastewater discharge for TSS (100 mg/l), BOD₅ (50 mg/l), COD (100 mg/l), and for nitrogen and phosphorus (10 mg/l). According to (NER (National Environmental Regulations), 1999), high concentrations of nitrogen and phosphorus in surface water causes rapid algal bloom growth, thus changing the color of the water to greenish, which leads to the de-oxygenation of the water, hence killing aquatic life.

1.3 OBJECTIVES

1.3.1 Main objective

To evaluate the use of Alum sludge in treatment of wastewater effluent.

1.3.2 Specific Objectives

1. To determine the physico-chemical parameters of the wastewater effluent discharged to Namatala wetland from Namatala WSPs.
2. To determine the Aluminum concentration in the sludge from Manafwa water treatment plant.
3. To determine the optimum dosage of the alum sludge required for treatment of waste water effluent.

1.4 RESEARCH QUESTIONS

1. What are physico-chemical parameters of the wastewater effluent discharged to Namatala wetland from Namatala WSPs.
2. What is the Aluminium concentration of the alum sludge from Manafwa water treatment plant.
3. What is the optimum dosage of the alum sludge required for treatment of waste water effluent.

1.5 SCIENTIFIC JUSTIFICATION

High concentrations of nitrogen and phosphorus in surface water cause rapid algal bloom growth, thus changing the color of the water to greenish, which leads to de-oxygenation of the water, thus killing aquatic life since these living organisms lack oxygen for respiration to take place (Ruiz *et al.*, 2011). Also, high levels of TSS reduce the quality of effluent since it is discharged into the wetland stream, making it unsafe for human consumption as it results in digestive complications that include cholera, typhoid, among others (Trevino Quiroga, 2011).

Alum sludge has aluminum hydroxide and some non-toxic elements, which makes it a huge potential for beneficial reuse as a raw material in water and environmental engineering for wastewater treatment due to its large content of Al ions as a coagulant residual (S. Lucas, Marco, 2021).

Alum forms a fluffy aluminum hydroxide precipitate called floc on contact with water. Aluminum hydroxide (the principle ingredient in conventional antacids such as Maalox) combines with phosphorus to generate an aluminum-phosphate complex (Carleton and Cutright, 2020). Under normal conditions, this molecule is insoluble in water, therefore algal species cannot use the phosphorus it contains as food. As the floc gradually settles, phosphorus is eliminated from the water (Zhao *et al.*, 2021a). Hence, the use of alum sludge in wastewater effluent treatment provides environmentally friendly and cost-effective waste reuse.

1.6 GEOGRAPHICAL SCOPE

Namatala stabilization pond is located in Mbale city and was constructed in the low laying area of Namatala at 1107 altitude (N Y. , Handy GPs, 2023). The alum sludge was obtained from the Manafwa water treatment plant located close to the Manafwa River, which is about 17 km from Mbale town along the Mbale - Tororo road.



Figure 1: Namatala WSPs

Source; (N Y. , 2023)

Content scope

This research project is mainly focused on;

1. Physicochemical analysis of stabilization ponds wastewater effluent before and after treatment.
2. Characterization of a coagulant with focus on coagulation properties of the alum sludge.
3. Determination of optimum dosage of alum sludge in wastewater effluent from stabilisation ponds.

Time scope

The research project commenced in October,2023 and was completed in April, 2024

CHAPTER TWO: LITERATURE REVIEW

2.1 WASTE WATER EFFLUENT

Wastewater effluent is the liquid that is discharged from a wastewater treatment plant after the wastewater has been treated to remove pollutants (Naidoo and Olaniran, 2014). The quality of wastewater effluent varies depending on the level of treatment it has received. Primary treatment removes grease and suspended solids, while secondary treatment reduces nutrients and dissolved organic matter (Igbinosa and Okoh, 2009). Tertiary treatment can be used to remove additional pollutants, such as heavy metals and pathogens (Metcalf, Eddy and Tchobanoglous, 1991).

2.2 THEORY OF COAGULATION

According to Ang and Mohammad (2020), coagulation process is crucial to the reclamation or removal of contaminants from wastewater. The primary physicochemical treatment techniques used in industrial wastewater treatment to lower suspended particles and colloidal turbidity is the coagulation-flocculation process (Gautam and Saini, 2020). Previous research indicates that the coagulation process can remove up to 40% of nitrogen and organic compounds from wastewater (Sukmana *et al.*, 2021). Coagulation is the process by which suspended and polluting particles collide with one another to produce agglomerates that eventually form an insoluble agglomeration complex (Stechemesser and Dobiáš, 2005). In several research papers, settling time, a coagulant dosage, and PH are the key factors determining the removal of pollutants from wastewater. These factors will lead to the optimum conditions in the JAR test (Sukmana *et al.*, 2021).

2.2.1 MECHANISM OF COAGULATION/FLOCCULATION

The coagulation/flocculation mechanism generally consists of four steps: charge neutralisation, sweep coagulation, bridging, and patch flocculation (Sukmana *et al.*,

2021). Fig.2 illustrates the coagulation/flocculation mechanism. Repulsion happens because some of the colloidal particles in the coagulation process have a negative charge. In order to stabilise the colloid particles and eliminate any repulsive force, coagulant is added. A poly-electrolyte called coagulant brings the colloid's zeta potential near zero points. As a result, according to Amran et al. (2018), this procedure is known as the charge neutralisation mechanism. Moreover, amorphous metal hydroxides precipitate when a high concentration of metal salts is added to the water; this process, known as sweep coagulation, results in the progressive formation of huge lumps.

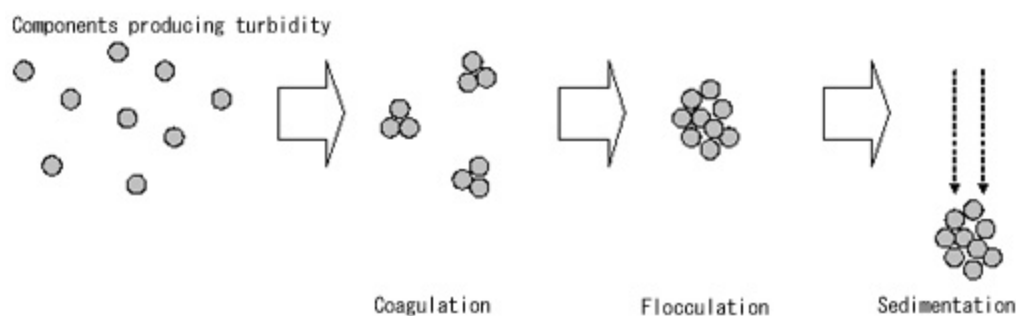


Figure 2: coagulation process.

Source: <https://www.safewater.org/fact-sheets-1/2017/1/23/conventional-water-treatment>.

Due to the adsorption of high molecular weight linear-chain chemicals, which are frequently based on polyacrylamide, the bridging flocculation process may result in the production of a very large floc. In several particles, this process takes place simultaneously (Sukmana *et al.*, 2021). Meanwhile, a local charge reversal is brought about by the polymer's adsorption onto the particles, which causes the patch flocculation

process. Each particle experiences an attraction force as a result of this process (Sukmana *et al.*, 2021).

2.2.2 COAGULANT SELECTION

The choice of coagulant chemical depends upon the type of suspended solid to be removed, raw water conditions, facility design, and cost of chemical (Cañizares *et al.*, 2009). The final selection of coagulant (or coagulants) should be made with jar testing and plant scale evaluation (Zane Satterfield, 2005). Consideration must be given to required effluent quality, the effect on downstream treatment process performance, the cost, method, and cost of sludge handling and disposal, and the cost of the dose required for effective treatment (Stechemesser and Dobiáš, 2005).

Coagulants are divided into two categories: chemical and natural. Both coagulants seek to eliminate contaminants in their physical (suspended solids and turbidity) or chemical (BOD and COD) forms (Kumar, Othman and Asharuddin, 2017). Chemical coagulant comprises pre-hydrolysing metallic salts like poly aluminum chloride (PAC), poly ferric chloride (PFC), poly ferrous sulphate (PFS), poly aluminum ferric chloride, and aminoethyl polyacrylamide, as well as synthetic cationic polymers like polyalkylene, polyethyleneimine, and polyamine. Hydrolysing metallic salts like ferric chloride, ferric sulphate, magnesium chloride, and alum is also included in this process. Natural coagulants include plant- and animal-based materials like starch and fruit waste, as well as microorganisms like bacteria, microalgae, and fungi. Animal-based materials include chitosan and isinglass (Sukmana *et al.*, 2021).

2.2.3 SEDIMENTATION

Sedimentation is the process of removing suspended particles such as flocs, sand, and clay from water. Sedimentation can occur naturally in reservoirs or in compact settling

structures. Examples of settling installations include horizontal flow tanks, tilted plate settlers, and floc blanket systems (Carlsson, 1998).

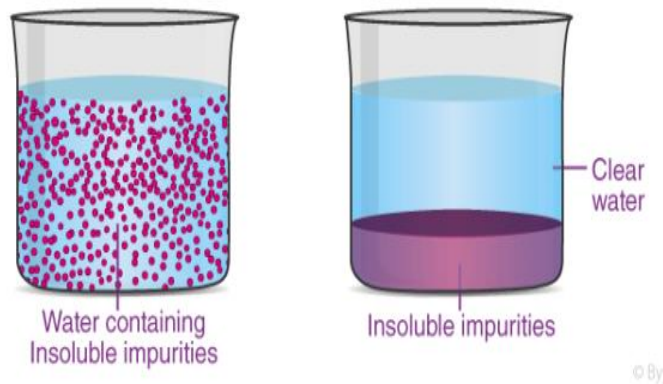


Figure 3: sedimentation process.

Source: Google

Sedimentation happens due to the difference in density between suspended particles and water. The sedimentation process is influenced by various parameters, including suspended particle density and size, water temperature, turbulence, flow stability, bottom scour, and flocculation (The Authors Team, 2020).

Types of settling

- Discrete particle settling. The particles sink without contact and occur at low solid concentrations. Sand particles are commonly removed as a result of this form of settling.
- Flocculent settling. This phenomenon occurs when particles settle independently but then flocculate in the clarifier's depth. The velocity of settling particles often increases when the particles agglomerate. The mechanics of flocculent settling are not fully understood.

- Hindered settling. Inter-particle forces are strong enough to prevent nearby particles from settling together. Particles tend to remain in stable locations relative to each other. This type of settling is common in the activated sludge process (secondary clarifier).
- Compression settling. High particle concentrations can cause mechanical influence between particles at different levels. The settling velocity then dramatically decreases.

2.3.1 WASTE WATER EFFLUENT CHARACTERISTICS

Wastewater effluent parameters are the physical, chemical, and biological characteristics of wastewater that are measured to assess its quality and suitability for reuse. Wastewater parameters are used to determine the degree of water pollution (Lokhande, Singare and Pimple, 2011). These are indicators of water pollution and are used to ensure that wastewater meets local standards. The most common wastewater effluent parameters include:

Physical characteristics: These include; color, temperature, turbidity, odor, and suspended solids. Wastewater is typically gray or brown in color, turbid, has an unpleasant odor, and contains a variety of suspended solids, such as feces, food scraps, and paper fibers (Hamidian *et al.*, 2021).

Chemical characteristics: These include, total dissolved solids (TDS), pH, electrical conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients (nitrogen and phosphorus), and heavy metals. Wastewater typically has a pH of 7-8, a high electrical conductivity due to the presence of dissolved salts, a

high TDS, a high BOD and COD due to the presence of organic matter, and elevated levels of nutrients and heavy metals (Hamidian *et al.*, 2021).

Biological characteristics: These include bacteria, viruses, protozoa, and helminths. Wastewater can contain a variety of pathogens that can cause diseases in humans, such as E. coli, Salmonella, and the hepatitis A virus (Hamidian *et al.*, 2021).

Some of the parameters are discussed below;

1. Biochemical oxygen demand (BOD)

BOD is a measure of the amount of oxygen consumed by microorganisms as they decompose organic matter in water. BOD is expressed in milligrams of oxygen consumed per liter of water over a specified period of time, typically 5 days at 20 degrees Celsius (Lokhande, Singare and Pimple, 2011).

BOD is an important water quality parameter because high BOD levels can deplete the oxygen levels in rivers and lakes, killing aquatic life. BOD is also a measure of the amount of organic pollution in water (Lokhande, Singare and Pimple, 2011).

2. pH

The pH of effluent is the acidity or alkalinity of the wastewater that has been treated by a wastewater treatment plant. The pH of effluent is important because it affects the effectiveness of wastewater treatment processes and the suitability of the effluent for reuse. (Boczka and Fernandes, 2017)

The ideal pH for wastewater effluent is between 6.5 and 8.5. This pH range is suitable for most aquatic life and for most reuse applications. However, the specific pH requirements for effluent reuse may vary depending on the intended use. For example, effluent that is to be reused for irrigation may need to have a lower pH to prevent the buildup of salts in the soil (Boczkaj and Fernandes, 2017).

The pH of wastewater effluent can be affected by a number of factors, including the type of wastewater being treated, the wastewater treatment processes being used, and the chemicals that are added to the wastewater during treatment (Christensen *et al.*, 2015).

3. Chemical oxygen demand (COD)

Chemical oxygen demand is a measure of the amount of oxygen required to oxidize all oxidizable organic matter in a water sample. COD is expressed in milligrams of oxygen consumed per liter of water (mg/L) (Boyles, 1997).

COD is a crucial water quality parameter because it can be used to assess the amount of organic pollution in water and the potential for dissolved oxygen depletion. High COD levels can deplete the oxygen levels in rivers and lakes, killing aquatic life. COD can also be used to assess the performance of wastewater treatment plants and the suitability of wastewater effluent for reuse (Can *et al.*, 2014).

COD is measured using a test called the COD test. The COD test involves adding a strong oxidizing agent, such as potassium dichromate, to a sample of water. The sample is then heated for a period of time to allow the oxidation reaction to occur. The amount of oxygen consumed by the oxidation reaction is then measured. The COD of the sample is

calculated by subtracting the amount of oxygen remaining in the sample at the end of the test from the amount of oxygen present in the sample at the beginning of the test (Jouanneau *et al.*, 2014).

4. TOTAL PHOSPHOROUS

Total phosphorus (TP) is a measure of all the phosphorus found in a water sample, whether that phosphorus is dissolved or particulate. TP is expressed in milligrams per liter (mg/L) (Turcios and Papenbrock, 2014).

TP is one of the water quality parameters used to assess the quality of wastewater because phosphorus is a nutrient that can stimulate the growth of algae and other aquatic plants. Excessive algae growth, also known as eutrophication, can lead to a number of problems, including:

- Reduced oxygen levels in the water, which can kill fish and other aquatic life.
- Turbidity and unpleasant odors.
- Increased risk of harmful algal blooms, which can produce toxins that can harm human health and aquatic life.

5. NITRATES

Nitrates are a type of nitrogen compound that is found in water and soil. Nitrates are essential for plant growth, but high levels of nitrates in water can be harmful to human health and aquatic life.

Nitrates can enter water bodies from a variety of sources, including:

- Sewage, animal manure, agricultural runoff, industrial wastewater, and atmospheric deposition

Nitrates are also a byproduct of the natural decomposition of organic matter (Turcios and Papenbrock, 2014).

Nitrates are an important parameter to monitor in wastewater treatment plants and in rivers and lakes. Wastewater treatment plants are designed to reduce the nitrate levels of wastewater before it is discharged into rivers and lakes. Nitrate removal is typically achieved through a biological process called denitrification (Turcios and Papenbrock, 2014).

Nitrates are also a useful parameter for monitoring the quality of rivers and lakes. High nitrate levels in a river or lake can indicate that the water body is polluted and that eutrophication may be occurring.

2.4.1 TYPES OF WASTEWATERS

Wastewater has different properties based on its release and source. The main pollutants found in wastewater and the importance of each.

Some examples of wastewater types are as follows:

- Domestic wastewater, which is discharged from homes.
- Wastewater discharged by municipalities (from communities).
- Wastewater from industry that is released (Pabbati and Reddy, 2021).

2.4.2 STAGES OF WASTEWATER TREATMENT

Wastewater is generated from industrial establishments and residential. It includes household waste liquid from toilets, sinks, showers, kitchens, baths, and others that is disposed of via sewers (Manasa and Mehta, 2020). In most places, sewage also includes liquid waste from commerce and industry. In the industrialised world, it is becoming increasingly typical to separate and drain domestic waste into separate categories, such as blackwater and greywater. Greywater is water that is produced by household tasks like washing clothes and dishes and is more easily recycled (Li, Wichmann and Otterpohl, 2009). Human waste can be found in blackwater, which originates from toilets (van Voorthuizen *et al.*, 2008). Preliminary, primary, secondary, and tertiary treatments are the three phases of sewage treatment (Demirbas, Edris and Alalayah, 2017).

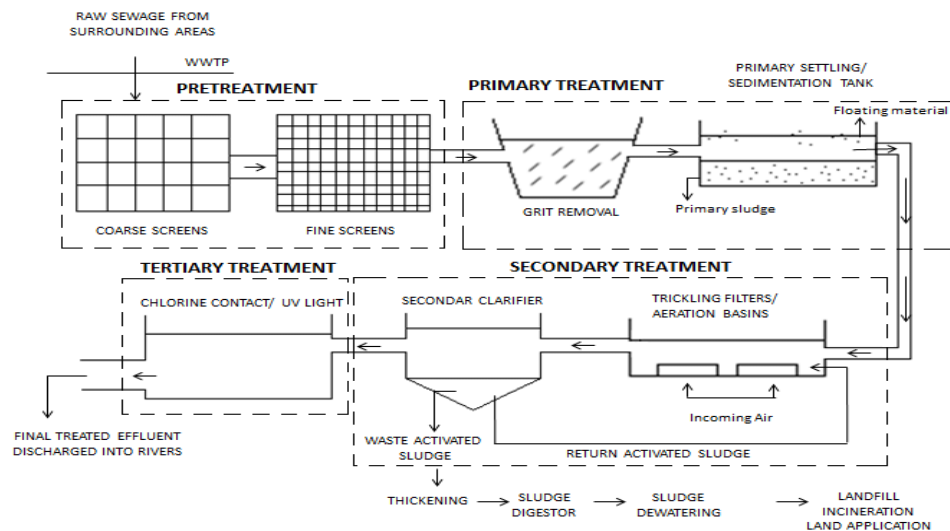


Figure 4: Wastewater treatment stages.

Source: ('Overview-of-treatment-stages-within-a-wastewater-treatment-plant-Adapted-from-EPA-16', no date)

Preliminary Treatment

During the initial treatment, glass bottles, plastics, floating objects including paper, wood, sticks, tree branches, diapers, napkins, and leaves must be removed, as must dead animals, as well as other heavy, settleable inorganic solids such as grit, oils, sand, fats, and grease-like materials. There are certain tools made specifically for doing first treatment, such as skimming tanks, grit chambers, and screeners (Pabbati and Reddy, 2021).

Primary treatment

Wastewater is kept in a basin for first treatment, where oil and lighter materials float to the top and solids (sludge) sink to the bottom. After removing these layers, the liquid that is still there can be transferred for further treatment. Sludge digestion is a distinct procedure used to treat sewage sludge (Zhuang *et al.*, 2020).

Secondary treatment

In a regulated setting, microbes are frequently used in secondary treatment to eliminate suspended and dissolved biological matter (Giannakis *et al.*, 2016). Aerobic organisms, which consume the organic (sugar, fat, and other materials) components of sewage, provide the basis for the majority of secondary treatment systems. Water passes through filters that support the growth of bacteria in certain fixed-film systems. Suspended growth systems make use of "activated" sludge, which is created by mixing decomposing bacteria straight into sewage. Because oxygen is essential for bacterial growth, sewage is frequently combined with air to aid in decomposition (Pérez-Mora *et al.*, 2023).

Tertiary treatment

When water is being released into an ecosystem that is delicate, tertiary treatment is also known as effluent polishing, it is utilised to further purify the water. Sewage can be further disinfected using a variety of techniques after undergoing primary and secondary treatment (Zagklis and Bampos, 2022). Particulate matter can be eliminated using sand filtration, which involves running water through a sand filter. It is possible for wastewater to include significant amounts of nutrients like phosphorous and nitrogen. These can lead to weed growth that is out of control, algae blooms, and disturbances in the nutritional balance of aquatic ecosystems (Ruiz *et al.*, 2011). Enhanced biological phosphorus removal is a method of biologically removing phosphorus. This process involves the increase of organisms that store phosphate in their tissue caused by polyphosphate-producing bacteria. When the biomass accumulated by these bacteria is removed from the treated water, the resulting biosolids have a high fertilizer value. Nitrifying bacteria is another way for nitrogen removal. Another method for removing debris and nutrients from sewage is lagooning. A lagoon stores water, while native plants, bacteria, algae, and small zooplankton filter nutrients and microscopic particles from the water (Process, no date).

2.4.3 WASTEWATER TREATMENT TECHNIQUES

Wastewater treatment techniques are categorized as conventional and non-conventional based on the method used to remove contaminants from the waste water. The choice of the most appropriate waste water treatment technique depends on various factors, such

as the composition of the waste water, the availability of resources, and the desired treatment goals (Dhote, Ingole and Chavhan, 2012).

Conventional waste water treatment techniques.

Conventional techniques rely on physical and chemical processes such as screening, sedimentation, filtration, coagulation, and oxidation to remove pollutants (Zinicovscaia, 2016).

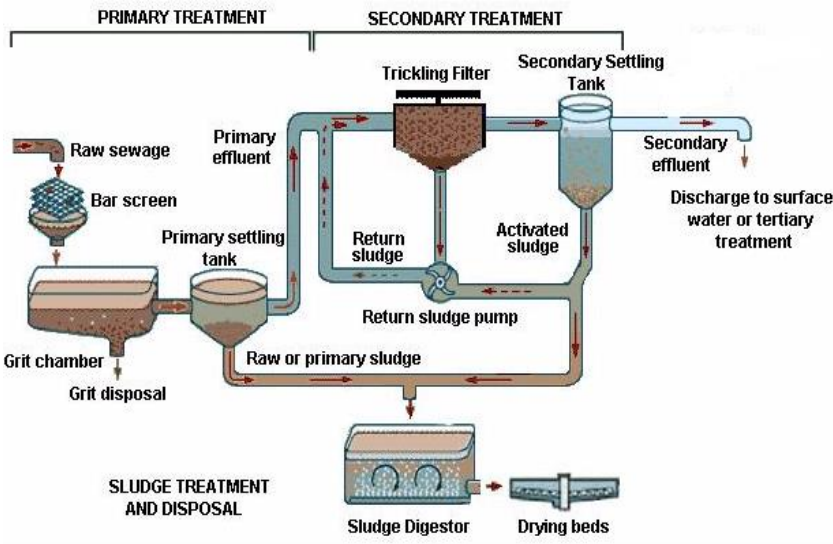


Figure 5: Conventional treatment process.

Physical: the use of physical techniques such as screening, sedimentation, and among others, has been shown to be effective in the removal of large particles, TSS and organic matter from wastewater (Crini *et al.*, 2019).

- Screening, removes large objects such as rags, sticks, and leaves from wastewater.

- Sedimentation, allows suspended solids to settle out of the wastewater by gravity.

Chemical: the use of chemical techniques such as coagulation/flocculation and chemical oxidation has also been shown to be effective in the removal of TDS and organic matter.

- Coagulation, addition of a chemical that can destabilize the surface charges of colloids and enhance agglomeration.
- Flocculation, process where a solute comes out of solution in the form of floc. Often used to mean the process by which fine particulates are caused to clump together into floc.

Non-conventional wastewater treatment techniques

Biological: the use of biological techniques such as aerobic and anaerobic treatment has been shown to be effective in the removal of organic matter and nutrients from wastewater (Crini *et al.*, 2019).

Constructed wetland: the use of constructed wetland has been shown to be effective in the removal of organic matter and nutrients from waste water. Constructed wetlands for wastewater treatment can be categorized as either Free Water Surface (FWS) or Subsurface Flow (SSF) systems (Kayombo, 2005). In FWS systems, the flow of water is above the ground, and plants are rooted in the sediment layer at the base of the water column (Kayombo, 2005). In SSF systems, water flows through porous media such as gravels or aggregates, in which the plants are rooted, vegetation types, and water column contacts in constructed wetlands (Kayombo, 2005).

2.5.1 WASTEWATER STABILISATION PONDS.

Waste stabilisation ponds are big, shallow basins that are typically rectangular in shape, where wastewater is continuously brought in and taken out (Von Sperling, 2007). The primary agents of the biological therapy that takes place in ponds are microalgae and bacteria. Man does not play a role in this process; all he does is provide enough room for it to happen in a controlled way (Mondiale La Sante, Mara and Pearson, no date).

2.5.2 Types of ponds

Anaerobic ponds, facultative ponds, and aerobic ponds are the three main forms of waste stabilisation ponds that are frequently utilised in Uganda and other countries, maturation pools (Spellman and Drinan, 2014). As the name suggests, anaerobic ponds have no dissolved oxygen and very little to no algae. Facultative and maturation ponds are sometimes known as photosynthetic or natural ponds, because of their abundant algae populations, which are crucial to the stabilisation of waste (Pearson, 2003). Maturation ponds are occasionally used to improve the bacteriological quality of the final effluent from conventional sewage treatment plants; they are then referred to as polishing ponds. Similarly, facultative ponds are separated into primary and secondary facultative ponds, which accept raw and settled sewage, respectively (the latter being the effluent from anaerobic ponds) (Mondiale La Sante, Mara and Pearson, no date).

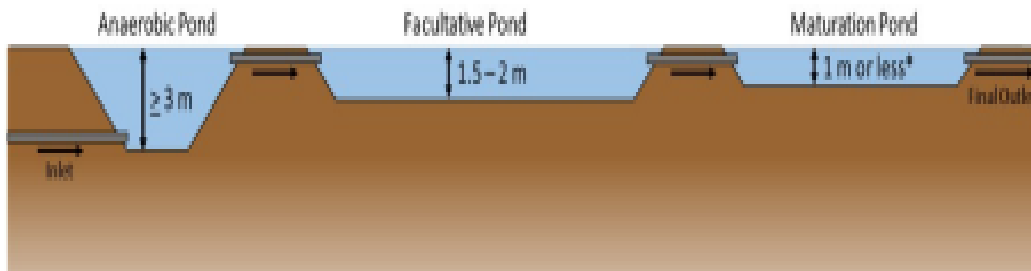


Figure 6: wastewater stabilisation ponds.

Source: (Verbyla, Sperling and Maiga, 2017).

Anaerobic ponds

Anaerobic ponds are typically 2-5 meters deep and accept wastewater with significant organic loads (Kayombo, 2005). Anaerobic ponds are deep wastewater treatment ponds that restrict oxygen and promote algae growth while also containing bacteria that help break down the effluent. The anaerobic pond primarily functions as an uncovered tank in which organisms break down the organic content in the effluent, generating methane and carbon dioxide (Trevino Quiroga, 2011). The process of anaerobic digestion is more intense at temperatures above 15° C (Appels *et al.*, 2010). Anaerobic bacteria are typically sensitive to pH below 6.2 (Kayombo, 2005).

Facultative pond

Facultative waste stabilization ponds, also known as lagoons or ponds, are widely utilized to treat municipal and industrial wastewater (USEPA, 2000). Facultative ponds (1-2 m

deep) are divided into two types: primary facultative ponds, which receive raw wastewater, and secondary facultative ponds, which receive particle-free wastewater (Sah *et al.*, 2011). In primary or secondary facultative ponds, aerobic bacteria typically dominate the process of oxidizing organic materials (USEPA, 2000). The facultative pond is a combination of aerobic and anaerobic zones. The aerobic zone is located at the surface of the pond, where oxygen is present, and the anaerobic zone is located at the bottom of the pond, where oxygen is absent (Dugan¹ and Oswald, 1968). The facultative pond is used to further remove organic matter and suspended solids (Kayombo, 2005).

Maturation pond

The maturation pond is the final one in the series. The maturation pond is used to polish the effluent and remove any remaining pollutants (Tanner *et al.*, 2005). The maturation pond is also used to kill off any pathogens that may be present in the effluents (Al-Hashimi and Hussain, 2013). Maturation ponds are usually 1-1.5 m deep and receive the effluent from the facultative ponds (Trevino Quiroga, 2011).

2.6 STANDARDS OF WASTEWATER DISCHARGE ACCORDING TO WATER ACT, CAP 152

It establishes the framework for regulating wastewater discharge through permitting and gives other rules the authority to define those criteria. Section 4 of the Water (Waste Discharge) Regulations, 1998 (Statutory Instrument No. 32 of 1998) bans the discharge of wastewater without a permit issued by the Director of Water Resources. Section 27 of the Environment Statute of 1995 (National Environment Act) requires the Director of Water Resources to communicate with the lead agency before establishing

standards for treated effluent or wastewater before discharge. This means the specific standards are likely outlined in a separate Statutory Instrument under the National Environment Act(MWE, 1998).

These are some of wastewater discharge of effluent or waste water permissible limits

S/N	Parameters	Limits (MAX)
1	pH	6.0-8.0
2	BOD ₅	50mg/l
3	COD	100mg/l
4	TDS	1200mg/l
5	Total phosphate	10mg/l
6	Color	300 PtCo
7	Turbidity	300NTU
8	TSS	100mg/l
9	Magnesium	100mg/l
10	Total Nitrogen	10mg/l
11	Iron	10mg/l
12	Copper	1.0mg/l

Table 1: Maximum permissible limit.

2.7 ALUM SLUDGE CHARACTERISATION

Alum sludge is a byproduct of the water treatment process when aluminum (Al) salts are used as a primary coagulant (Niwagaba *et al.*, 2019). It is generated when aluminum salts are used as coagulants to remove impurities from water (Dassanayake *et al.*, 2015). Because of their effectiveness and low cost, aluminum salts are the most often used primary coagulating agents in water treatment procedures around the world (Dassanayake *et al.*, 2015). Hence, alum sludge is the most extensive by-product generated by water industries across the world. Alum sludge is typically composed of aluminum hydroxide, solids from the raw water, and other chemicals added during the water treatment process (Barakwan, Trihadiningrum and Bagastyo, 2019). Aluminum (Al) as an element is well-known to possess a strong affinity for phosphorous (Muisa *et al.*, 2020).

The composition of dry alum sludge can vary depending on the source of water, but typically contains the following components;

Elements	Composition
Aluminum oxides and hydroxides	70-90%
Calcium sulfate	5-10%
Iron oxides	5-15%
Silica	2-5%
Heavy metals	-

Table 2; Alum sludge composition.

Wet alum sludge is a slurry of dry alum and water, and this typically consists dry alum solids (10-20%) and water (80-90%). The main difference between dry and wet alum sludge is the water content; dry alum sludge has a water content less than 10%, while wet alum sludge has a water content of 80-90% (Xu *et al.*, 2016).

Formation of alum sludge

- During water treatment, alum is added to raw water to destabilize suspended particles and cause them to clump together. These clumps, called floc, settle to the bottom of the treatment tank.
- The clear water at the top is then filtered and disinfected before being distributed as drinking water.
- The settled floc, along with any other settled material, is removed from the tank as alum sludge.

2.8 LEACHING

Leaching is a process in which a liquid solvent is used to extract a desired substance from a solid material. The leaching process is done on alum sludge to recover the aluminum element in it. For alum sludge, the solvent used is typically a strong acid, such as sulfuric acid or hydrochloric acid. The acid dissolves the aluminum hydroxide, forming a solution that can then be separated from the solid residue. The concentration of alum sludge can be determined by measuring the amount of aluminum in the leachate solution, and analytical techniques such as Atomic Absorption Spectroscopy (AAS) are used (Cheng *et al.*, 2012).

Leaching can be carried out in a variety of ways, but the most common approach is to use a batch reactor. In a batch reactor, the alum sludge is mixed with the leaching solvent in a closed vessel. The mixture is then agitated for a period of time to allow the aluminum hydroxide to dissolve. Once the process is done, the leachate solution is separated from the residue (Boaventura, A. R., Duarte, A. S. A. & Almeida, 2000).

2.9 JAR TEST

Jar tests are laboratory tests used to stimulate the coagulation and flocculation process that occur in water treatment plants (Sengul and Gormez, 2013). It is used to determine the optimal amount of coagulant needed to remove pollutants from water. The jar test is carried out with a jar test apparatus, which consists of six or more jars agitated at varying rates. Each jar receives a sample of water, followed by varying quantities of coagulant and flocculant. The jars are swirled for a certain amount of time, and the flocs are allowed to settle. The supernatant's clarity is tested to determine the efficiency of the coagulant and flocculant dosages (Pivokonský *et al.*, 2022).

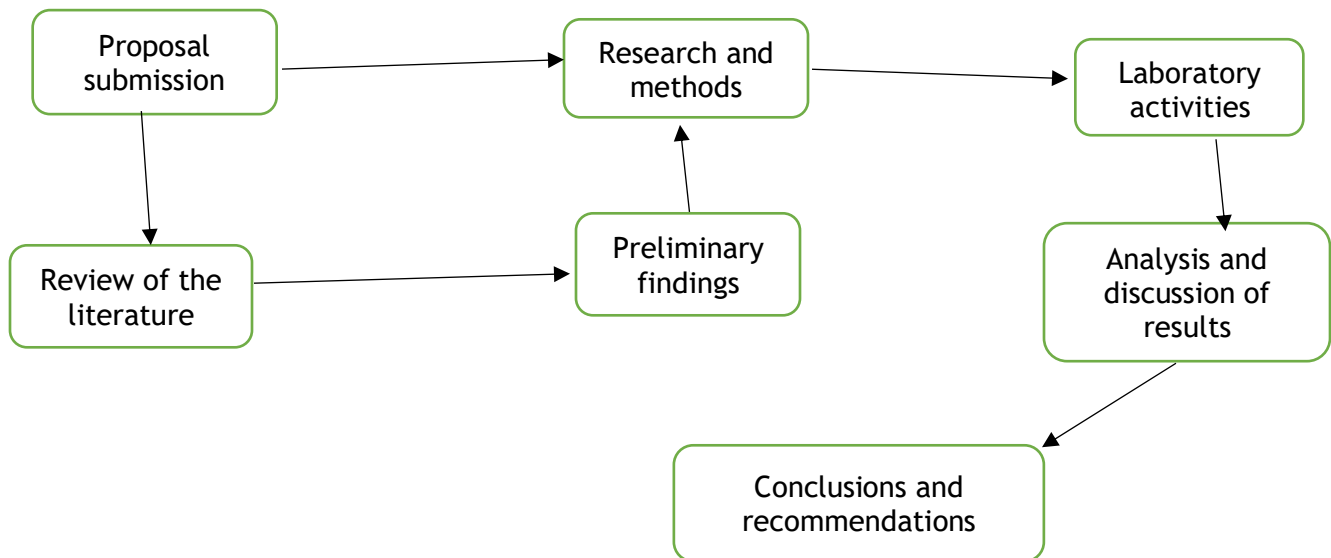
CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter includes the research methods and procedures used to obtain results that will be incorporated during the research.

3.1 Research Design

The research followed the systematic procedure that was informed by previous studies, which entails the use of alum sludge.



3.2 SAMPLE COLLECTION, STORAGE AND PRESERVATION FOR WASTEWATER EFFLUENT

The objective of sampling is to gather a representative sample of material that is small enough in volume to be easily transported but large enough for analytical purposes while accurately representing the substance under consideration.

The procedure details sample collection, storage, and preservation before analysis for wastewater effluent. These include the required sampling containers, sample volumes, preservation techniques, and holding times to ensure the integrity of the sample.

Procedure

1. The bottles were labeled before taking the samples to avoid the problem of trying to write on the wet bottles.
2. For better results, bottles were cleaned with distilled water to prevent contamination from affecting the quality of the sample.
3. Fill sample containers—without pre-rinsing—with samples.
4. Samples were collected at the sampling point, and it was done in triplicate on different times of the day that is, morning, afternoon and evening.
5. Each sample bottle was given a unique sample number, preferably by attaching an appropriate inscribed label or tag.
6. The samples were sealed and put in the cooling immediately to reduce the potential spillage or label deterioration and to maintain the conditions under which they were collected.
7. The samples were stored in an ice box with wet ice until they were analyzed.

3.2.2 WASTEWATER ANALYSES

Laboratory Analysis

The laboratory analysis was conducted using standard methods (APHA,1995) and specific methods and equipments were used to analyse each parameter as shown below.

S/N	PARAMETERS	STANDARD METHOD
1	PH	pH Electrode Test APHA 4500B
2	COD	Closed Reflux method 522 B (APHA, 1998)
3	BOD	5-day test method APHA 5210 B
4	TSS	2540-D (APHA, 1998)
5	TDS	APHA 2540 C
6	TP	Kjeldahl digestion method 4500-NC (APHA, 1998)
7	TN	Ascorbic method APHA 2120 C
8	EC	8156 pH Electrode test using Ph
9	COLOR	APHA 2120C
10	Turbidity	Turbidimeter (APHA 213B)

Table 3: Standard APHA procedures.

DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND

BOD is typically expressed as milligrams of oxygen per liter of sample during 5 days. The process involved, preparation of dilution sample, preparation and measurement of initial DO, preparation of blank sample, incubation of sample for 5 days at 20° c and determination of dissolved oxygen after 5 days.

DETERMINATION OF CHEMICAL OXYGEN DEMAND

COD was measured using a test called the COD test. The COD test involved adding a strong oxidizing agent, such as potassium dichromate, to a sample of water. The sample was then heated for a period of time to allow the oxidation reaction to occur. The amount of oxygen consumed by the oxidation reaction was then measured. The COD of the sample was calculated by subtracting the amount of oxygen remaining in the sample at the end of the test from the amount of oxygen present in the sample at the beginning of the test.

DETERMINATION OF TOTAL PHOSPHOROUS

A sample was prepared and appropriate reagents were added that is, sulfuric acid solution, potassium antimonyl tartrate solution, ammonium molybdate and ascorbic solution. These reagents were mixed well and waited for the blue color to develop, which took 10 to 30 minutes and the absorbance of the blue complex was measured using a spectrophotometer at a wave length of 880nm.

DETERMINATION OF TOTAL NITROGEN

The sample was injected onto a platinum catalyst heated at $\geq 720^{\circ}\text{c}$. The sample converted into a gaseous phase and passed through the catalyst, converting all

nitrogen-containing compounds to nitrogen oxide (NO). Reacted with ozone to converted to NO₂ and the excited NO₂ returned to the ground state, it emitted radiations that was measured photo-electronically.

3.3.0 DETERMINATION OF ALUMINIUM CONCENTRATION IN THE ALUM SLUDGE

3.3.1 Material abstraction and preparation

Before using alum sludge as a coagulant, it is important to prepare and abstract it properly to ensure its effectiveness and performance. A slurry of an alum sludge was collected from Manafwa water treatment plant using a 20-liter jerrycan, which was air dried under shade and for further drying, the sample was oven dried, and grinded to improve its surface area, and abstraction was done through leaching process to produce a coagulant.

Leaching process (production of coagulant)

To attain the required normality (3.0 N), 82 ml of 98% laboratory grade sulphuric acid (H₂SO₄) was diluted with one liter of distilled water.

Solid loading ranges from 3 to 10 g WTS per 100 mL of leaching solution.

The leaching technique was carried out in 1,000 mL beakers with agitation provided by a VELP Scientifica JLT6 flocculation tester.

The mixing speed was adjusted at 50 rpm to achieve homogeneity during the leaching process, and the extraction time was 60 minutes.

The method was performed at room temperature and pressure, and after the prescribed hour of extraction, the unreacted particles were allowed to settle before the filtration phase began. The other parameters, including temperature and agitation, remained constant. Atmospheric leaching at room temperature was preferred because it

consumed less energy and was simpler to implement at WWTPs.

To save energy and money, agitation speeds were kept low, just enough to suspend the sludge particles. Solid loadings greater than 10% in leaching processes cause operational challenges in pumping and mixing as the solution becomes saturated, hence there was no reason to proceed beyond this figure.

3.3.2 Al content Analysis

The filtered extract was analysed for Al content by AAS. Samples were filtered via a 0.45 µm sterile syringe filter to avoid clogging of AAS liquid transfer tubes. Because the samples were too acidic for the AAS, they were diluted by a factor of ten with nitric acid. Al analysis also required five Al concentrations: 5.0, 10, 15, 20, and 25 ppm.

Because a nitrous oxide flame is used, the leachate samples were diluted by a factor of ten with 2.0% nitric acid before Al analysis.

3.4.0 JAR TEST

water samples were collected in 2 (20liter) jerrycans, and the water samples were poured into six glass jars, one for each one liter. The glass beakers were placed under the jar test machine. The water sample were dosed with different doses, i.e., 0.5, 1, 1.5 up to 6.0 ml/l of alum sludge extract. Rapid mixing was done in 2 minutes at 250 revolutions per minute, slow mixing for 15 minutes at 30 revolutions per minute, and the samples were left to settle for 30 minutes. The tests were done in 12 runs in order to determine the effective optimum dosage. (Refer to the annex for the full method)

3.5 PROTOTYPE MODE OF OPERATION

- Raw wastewater was poured in the coagulation bucket.
- Alum sludge extract was added to wastewater as coagulant.
- The water in the coagulation was then left to flow to the collecting bucket.
- The prototype was set for the retention time of 15 minutes.

3.6 DATA ANALYSIS AND INTERPRETATION

The results and data from the research were analysed using Microsoft Excel 2016 as a software tool, which aided in the computation of averages, which were helpful in determining the optimum dosages of Alum sludge extract.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents detailed results obtained from laboratory tests carried out on waste water effluent from waste treatment plant before and after treatment using the proposed use of alum sludge. It further presents the discussion of the results mathematically and graphically.

4.1 ANALYSIS OF PHYSICO-CHEMICAL PARAMETERS OF WWSPs WASTEWATER

EFFLUENT RESULTS

Samples of effluent at the exit of the maturation were collected at the discharge point, from where wastewater is poured into the Namataala wetland. They were then taken to the lab for analysis in order to indicate the effect of Namataala stabilisation ponds on Namataala wetland in mbale city. The samples were analysed in the laboratory for the following parameters:

- Biochemical oxygen demand, chemical oxygen demand, total nitrogen, and Total phosphorous

Parameters	Units	Morning	Afternoon	Evening	Mean	SD	Standards
BOD	mg/l	193.2	190.3	192.6	192	1.53	<50
COD	mg/l	222	250	235	235.7	14.01	<100
TN	mg/l	50	45	54	49.7	4.51	<10
TP	mg/l	30.3	30.7	30.4	30.5	0.21	<10

Table 4: preliminary results of wastewater effluent.

Total nitrogen (TN)

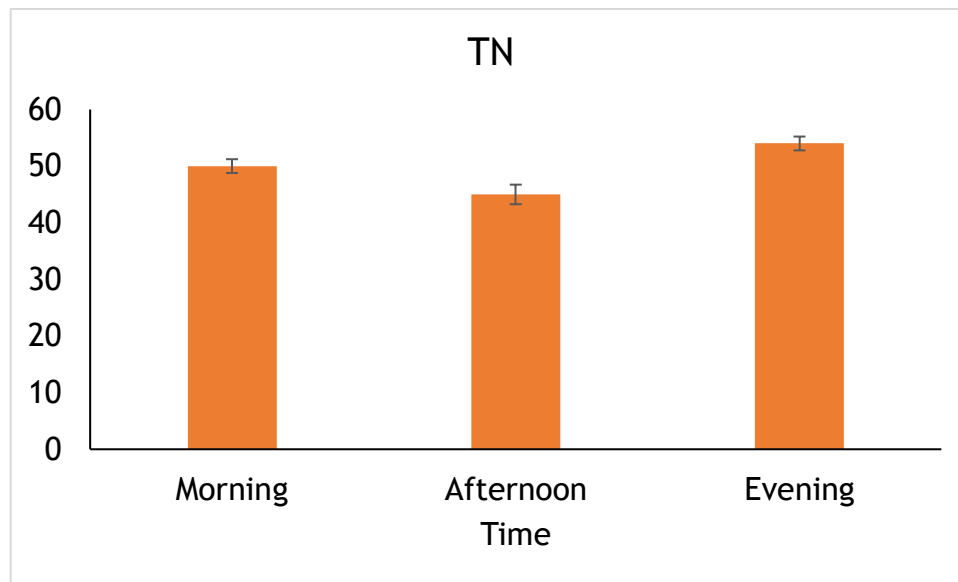


Figure 7: TN variation at different times of the day in effluent wastewater.

In the Morning, 50 ± 1.22 mg/l, Afternoon, 45 ± 1.75 mg/l, and Evening, 54 ± 1.22 mg/l, on average, had a TN of 50 ± 4.5 mg/l > 10 mg/l and high TN is due to high organic loading as indicated by high BOD, and it is also caused by the nitrification process, which leads to eutrophication of Namataala wetland.

Total phosphorous (TP)

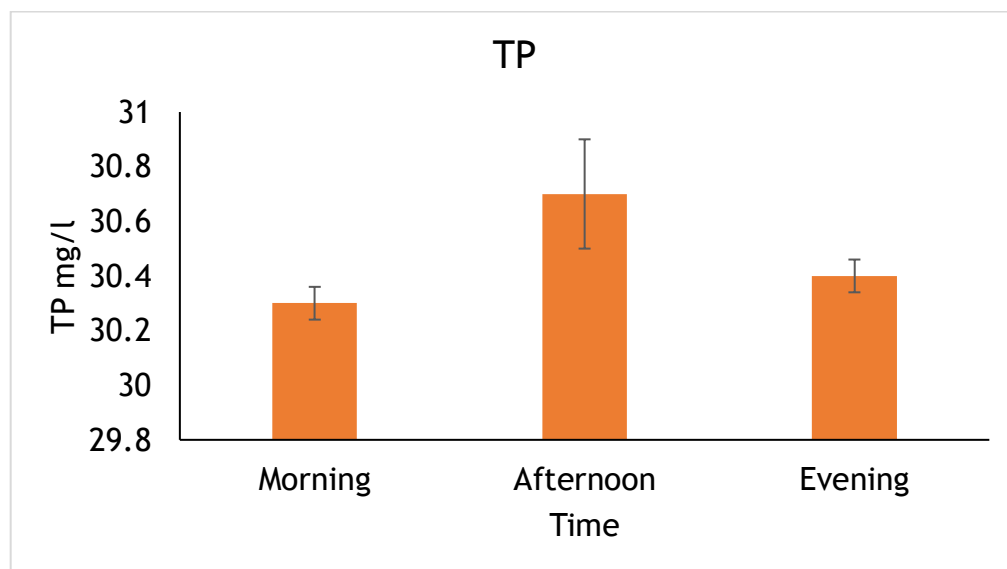


Figure 8: TP variation at different times of the day in effluent wastewater.

In the Morning, 30.3 ± 0.16 mg/l, Afternoon, 30.7 ± 0.20 mg/l, and Evening, 30.4 ± 0.17 mg/l, on average, TP of 30.6 ± 0.21 mg/l > 10 mg/l. High levels of TP are due to the growth of algae blooms in the facultative, which prevents sunlight from entering down and high levels of TP cause eutrophication to the namataala wetland.

Chemical oxygen demand (COD)

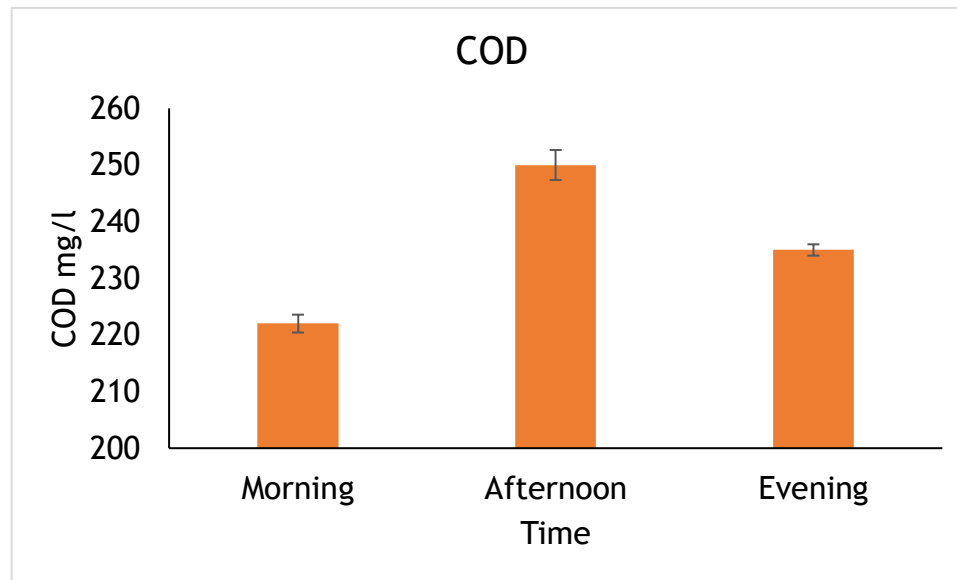


Figure 9: COD variation at different times of the day in effluent wastewater.

In the Morning, 222 ± 1.58 mg/l; Afternoon, 250 ± 2.65 mg/l; and Evening, 235 ± 1.0 mg/l which is above the discharge standards (100 mg/l), on average COD of 235.7 ± 14.0 mg/l > 100 mg/l, high COD is due to sludge accumulation (aerobic pond) and low hydraulic retention time. Therefore, high COD decreases DO available for aquatic life in Namataala wetland.

Biochemical oxygen demand (BOD)

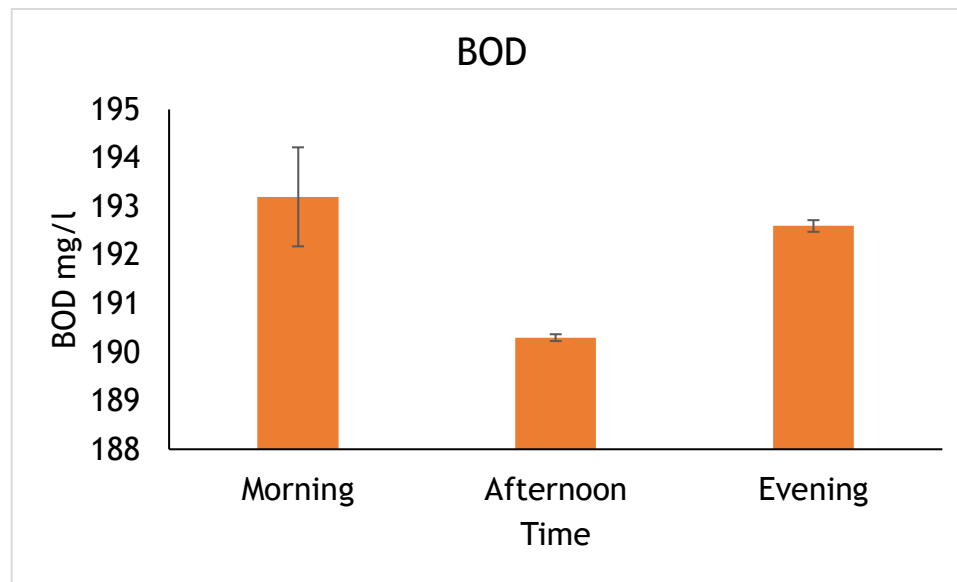


Figure 10: BOD variation at different times of the day in effluent wastewater.

In the Morning, 193 ± 1.02 ; Afternoon, 190.3 ± 0.07 ; and Evening, 192.6 ± 1.12 mg/l, and on average, had a BOD of 192 ± 1.5 mg/l which is above the discharge standards of 50 mg/l. High BOD is due to observed algae growth in facultative ponds, leading to high retention time and less contact time at the aerobic pond for microbes to degrade BOD.

4.2 ALUM SLUDGE ANALYSIS

Before the use of alum sludge as a coagulant for the treatment of wastewater effluent, there was a need to test for important parameters to ensure that it was suitable for the intended application.

In this research, the parameter that was tested in the alum sludge was Aluminium. Analyzing Aluminium is to ensure that the filtrate from alum sludge is suitable for use as a coagulant and is suitable to effectively remove pollutants from wastewater effluent without causing further contamination.

SAMPLE	test1	test2	test3	Mean	AL % CONC.
3g/100ml	405	390	397	397.33	13.24
5g/100ml	789	801	782	790.67	15.81
10g/100ml	1141	1140	1139	1140	11.4

Table 5: Aluminium concentrations of different weight of Alum sludge.

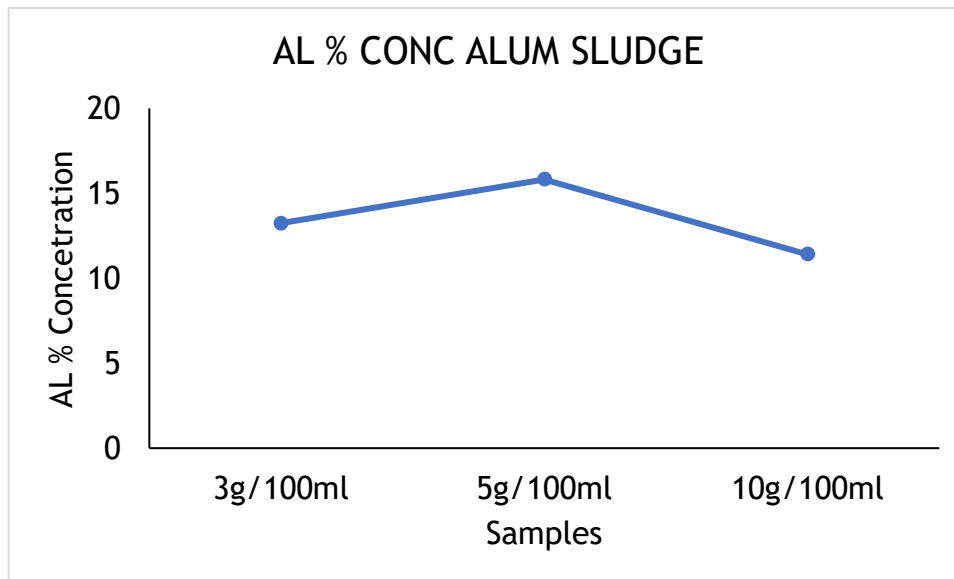


Figure 11: Aluminium concentration (%) variation with weight of alum sludge.

The sulphuric acid of 3.0 N was used in the extraction process. The highest percentage value of extracted Al was 15.81 mg/g of alum sludge at a solid loading of 5 g alum sludge/100 mL of H₂SO₄, and 3.0 N. 3.0 N gave an extraction pH range of 0.56-0.77 for the 5 g/100 mL solid loading. And for 3g of alum sludge/100 ml of H₂SO₄ the concentration, and for 10 g was 13.24 and 11.4; however, it was observed that the amount of alum recovered was increasing with an increase in alum sludge weight.

4.3 ANALYSIS OF OPTIMUM DOSAGE OF ALUM SLUDGE

The optimum dosage was determined by carrying out a jar test in which an alum sludge extract of 3 mg/l of sulphuric acid was used. The jar test was done in 12 runs in order to effectively determine the optimum dosage of alum sludge extract. The percentage reduction was calculated by the formula below;

$$\% \text{ removal} = \frac{(\text{initial value} - \text{final value})}{(\text{initial value})} \times 100$$

EFFECT OF THE COAGULANT ON TURBIDITY

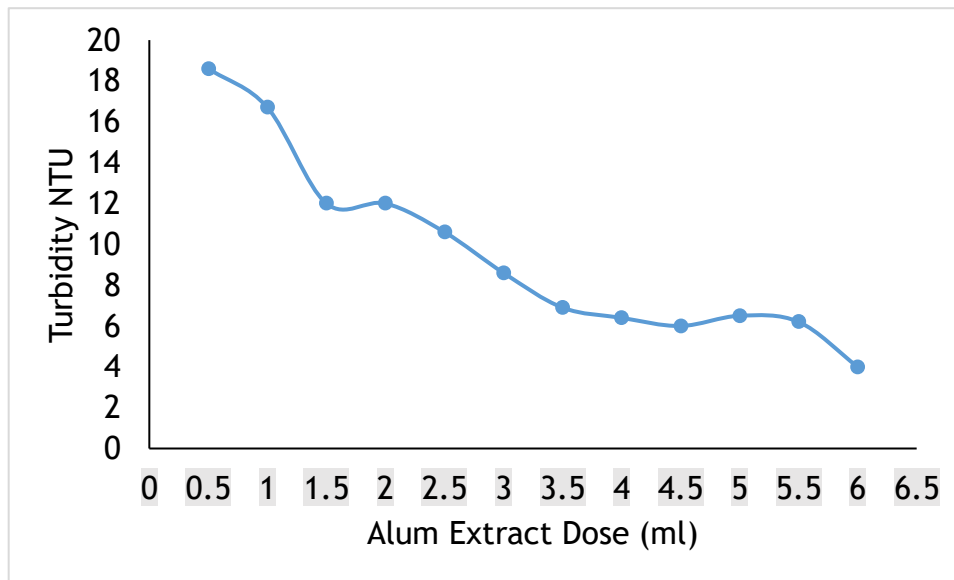


Figure 12: Turbidity variation with Alum sludge extract dose.

From the graph, turbidity values were seen to reduce with an increase in alum sludge extract from 18.6 to 6 (NTU) with an increasing dose of 0.5 to 4.5 ml/l. Effective turbidity removal, with lowest being 4 at a dose of 6 ml/l and 3.5 ml/l, was considered with a final turbidity of 6.5 NTU and a % reduction of 82.3%.

EFFECT OF THE COAGULANT ON pH

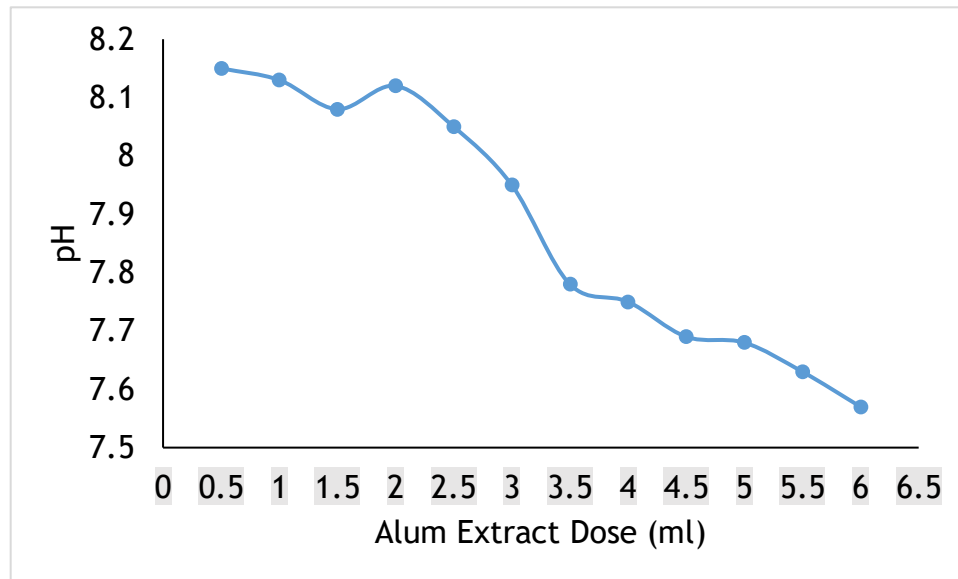


Figure 13: pH variation with the Alum sludge extract

There was a reduction in PH values with an increase in the dose of alum extract, where the final PH values were in the range of 8.15 to 7.57. The dose of 3.5 ml/l giving a PH of 7.78, was used since it's < (6-8) PH for allowable discharge standards. There was no need for pH correction since the pH values were in the range where coagulation effectively operates well, that is (6-8 range)

4.4.0 COMPARISON OF INFLUENT, EFFLUENT AND TREATED MATURATION POND

WASTEWATER PARAMETERS.

After determination of the optimum dosage of alum sludge extract, a proto-type was set and operated. Wastewater samples were collected at the inlet of the maturation pond and tested before and after treatment. The wastewater results of the influent of the maturation pond were analysed before and after treatment and effluent of the maturation pond, and were presented and discussed in the graphs below with the percentage removal of the pond, alum extract and alum extract more efficiency removal

compared to the maturation pond. The percentage removal was calculated using the formula below.

$$\% \text{removal} = ((\text{initial value} - \text{final value}) / (\text{initial value})) * 100$$

4.4.1 BIOCHEMICAL OXYGEN DEMAND

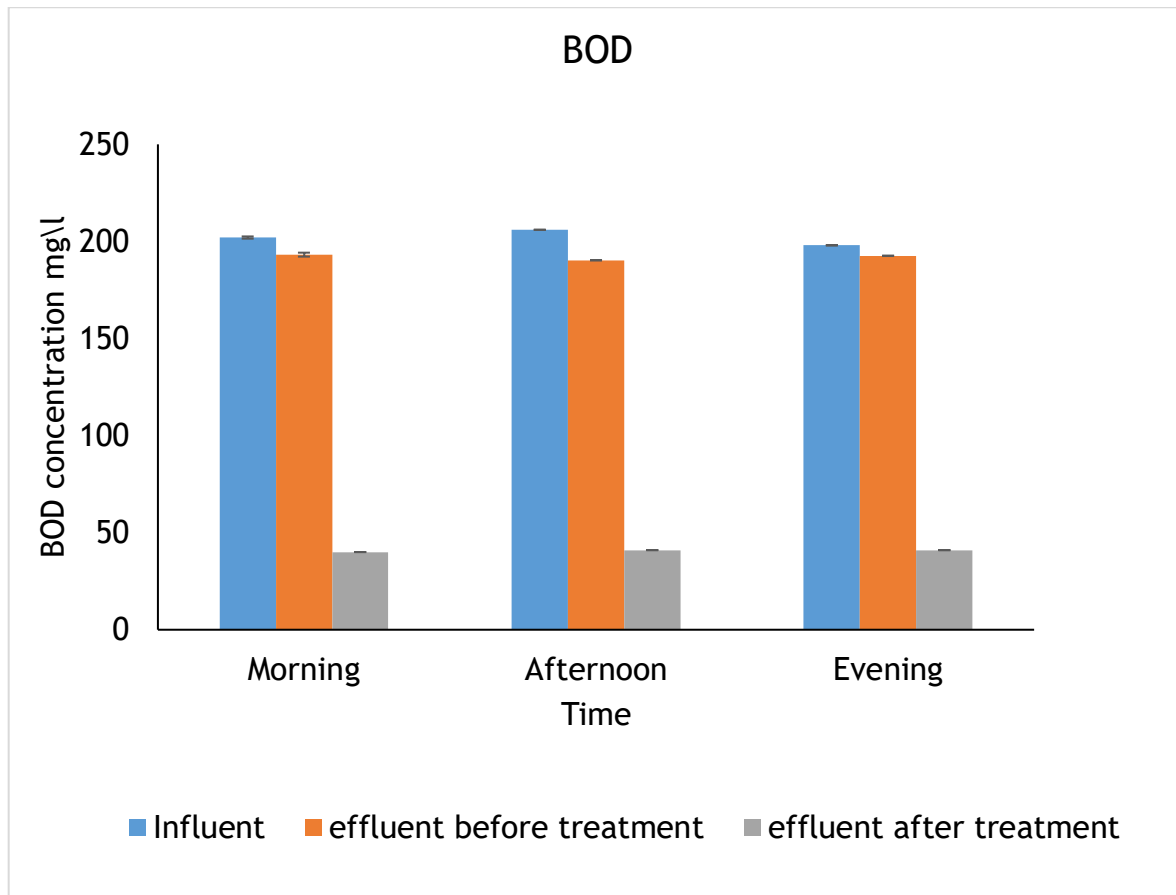


Figure 14: BOD of wastewater effluent from maturation pond and influent of maturation pond as well as effluent after treatment.

Morning: The influent BOD value was 202 ± 0.58 mg/l and decreased to 193 ± 1.02 mg/l at the maturation pond's exit, indicating a 4.4% reduction in BOD. The addition of alum extract demonstrated a high efficiency of 80.2%, resulting in a final of 40 mg/l, and the alum sludge extract demonstrated a 79.3% removal of BOD that was more efficient than

that of the maturation pond.

Afternoon: The influent BOD value was 206 mg/l, and it decreased to 190.3 ± 0.07 mg/l at the maturation pond's outflow, indicating an effective 7.6% reduction in BOD. When alum extract was added, the efficiency increased to 80.1%, and the final result was 41 mg/l. Alum sludge extract demonstrated a 78.5% increase in efficiency over the maturation pond.

Evening: At the maturation pond's exit, the influent dropped from 198 ± 0.12 mg/l to 192.6 ± 0.12 mg/l, indicating a 2.7% reduction in BOD. The addition of alum extract demonstrated a high level of efficiency, measuring 79.3%, and the final result was 41 ± 0.06 mg/l. The results also showed that the alum sludge extract was 78.7% more efficient than the maturation pond. Alum sludge extract on average demonstrated 79.9% and 78.8% better efficiency than the maturation pond, respectively, while the maturation pond averaged 4.9% BOD percentage reduction across three separate samples.

The amount of oxygen needed by wastewater microorganisms to break down organic matter is known as BOD. Microbes in wastewater use organic materials, such as proteins, carbohydrates, and lipids, as a food supply. These microbes need oxygen to break down the organic matter. This results in a high completion of oxygen, which impacts the aquatic life.

Alum extraction is added to sewage effluent to promote the production of flocs that settle as a result of coagulation and flocculation. As a result, organic matter is removed, which lowers the number of microbes and, ultimately, the BOD levels. Microbial competition for oxygen decreases in proportion to the decrease in organic matter.

4.4.2 CHEMICAL OXYGEN DEMAND

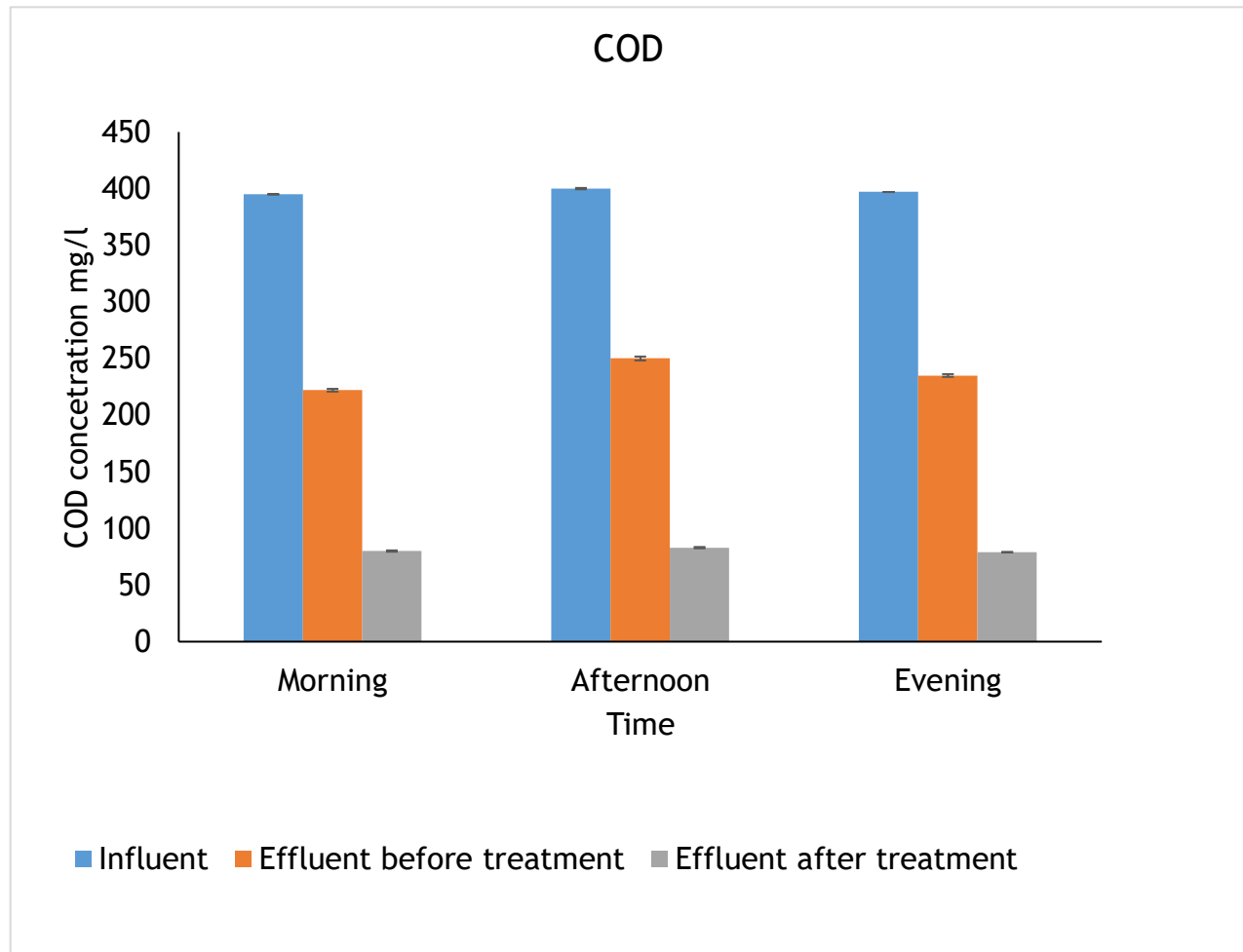


Figure 15: COD of wastewater effluent from maturation pond and influent of maturation pond as well as effluent after treatment.

Morning: The influent was 395 ± 0.25 mg/l and decreased to 222 ± 1.58 mg/l at the maturation pond's exit, indicating an efficient 43.8% reduction in COD. The addition of alum extract demonstrated a high level of efficiency of 79.7%, and the final result was 80 ± 0.58 mg/l. The extract from alum sludge demonstrated a 64.0% greater level of efficiency than the maturation pond.

Afternoon: The influent was 400 ± 0.58 mg/l and decreased to 250 ± 2.65 mg/l at the maturation pond's exit, indicating a 37.5% reduction in COD. The addition of alum

extract demonstrated a high level of efficiency of 79.3%, and the final result was 83 ± 0.58 mg/l. The results indicated that the alum sludge extract was 66.8% more efficient than the maturation pond.

Evening: When alum extract was added, the efficiency was 80.1% and the final result was 79 mg/l. Alum sludge extract demonstrated that it is 66.4% more efficient than the maturation pond. The influent was 397 mg/l and decreased to 235 ± 1.0 mg/l at the exit of the maturation pond, indicating an efficiency of 40.8% reduction of COD. Therefore, on average, the maturation pond demonstrated an average of 40.7% COD percentage reduction across three distinct samples. In comparison, the alum sludge extract demonstrated 79.7% and 65.7% greater efficiency over the maturation pond.

The total oxygen needed to oxidize both organic and inorganic matter in wastewater is measured by COD (carbon dioxide dosing): $\text{organic carbon} + \text{O}_2 \rightarrow \text{Energy} + \text{CO}_2 + \text{H}_2\text{O}$. The alum added to the wastewater binds together the organic and inorganic matter that settles, resulting in a reduction of organics and a decrease in overall oxygen demand and COD.

4.4.3 TOTAL NITROGEN

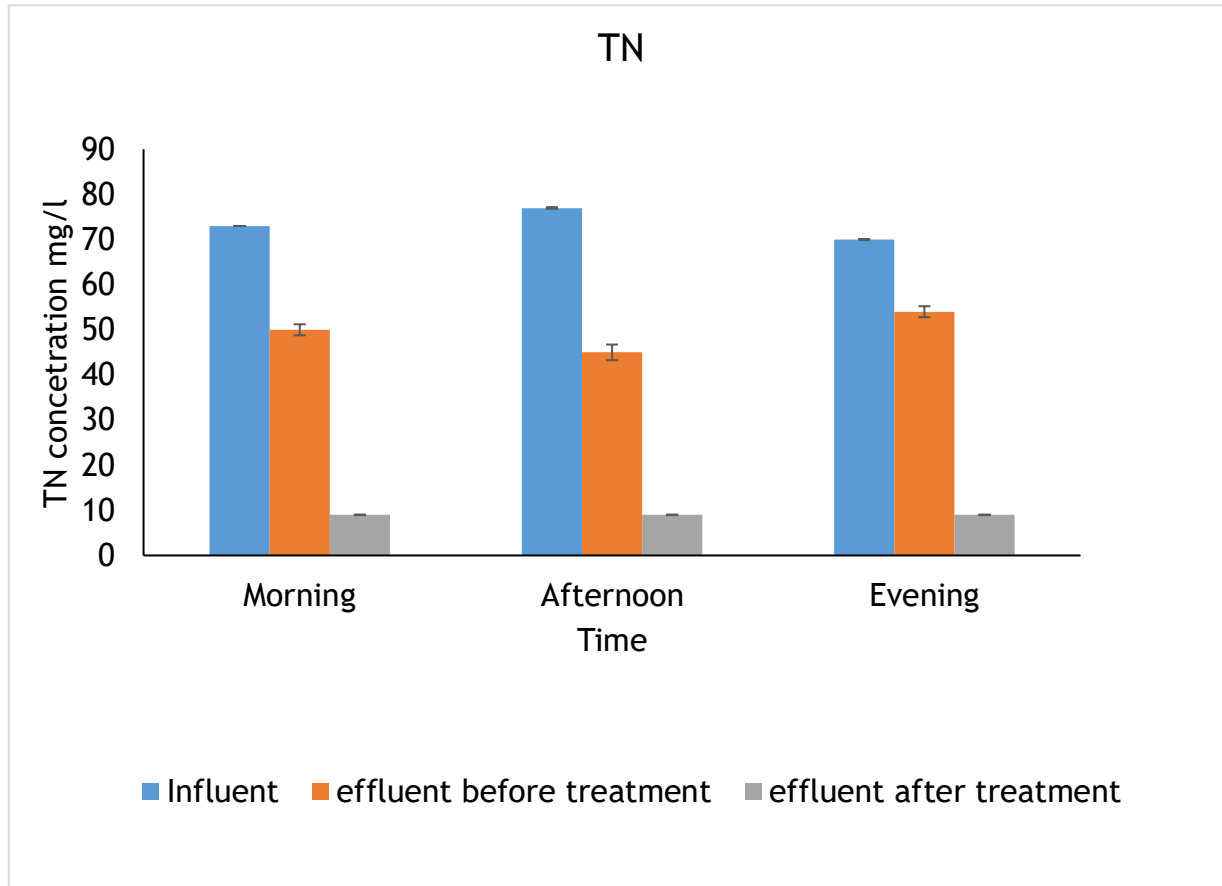


Figure 16: TN of wastewater effluent from maturation pond and influent of maturation pond as well as effluent after treatment.

Morning: The influent TN value was 73 mg/l and decreased to 50 ± 0.22 mg/l at the maturation pond's exit, indicating a 31.5% reduction in TN efficiency. The addition of alum extract led to a high efficiency of 87.7% and a final result of 9 ± 0.06 mg/l, indicating an 82% increase in efficiency over the maturation pond.

Afternoon: The influent TN value was 77 ± 0.17 mg/l and decreased to 45 ± 1.73 mg/l at the maturation pond's exit, indicating a 41.6% reduction in TN efficiency. The addition of alum extract led to a high efficiency of 88.3% and a final result of 9 ± 0.06 mg/l, indicating an 82% increase in efficiency over the maturation pond.

Evening: When alum extract was added, the efficiency was 87.1%, and the final result of TN was 9 ± 0.06 mg/l. Alum sludge extract demonstrated that it is 83.3% more efficient than the maturation pond. The influent was 70 ± 0.06 mg/l and decreased to 54 ± 0.122 mg/l at the exit of the maturation pond, indicating a 22.9% reduction of TN. On average, alum sludge extract demonstrated 87.7% and 81.8% better efficiency than the maturation pond, while the maturation pond averaged a 32% TN percentage reduction across three separate samples.

This is the measure of total nitrogen in wastewater, which is contributed by both inorganic and organic matter such as nitrate and nitrite. The breakdown of biodegradable organics releases ammonia ions, which are more likely to be converted to nitrate and nitrite, which are harmful to the environment. The treatment of wastewater using alum extract effectively converts nitrate and nitrite into harmless nitrogen gas, which is released into the atmosphere as atmospheric nitrogen.

4.4.4 TOTAL PHOSPHOROUS

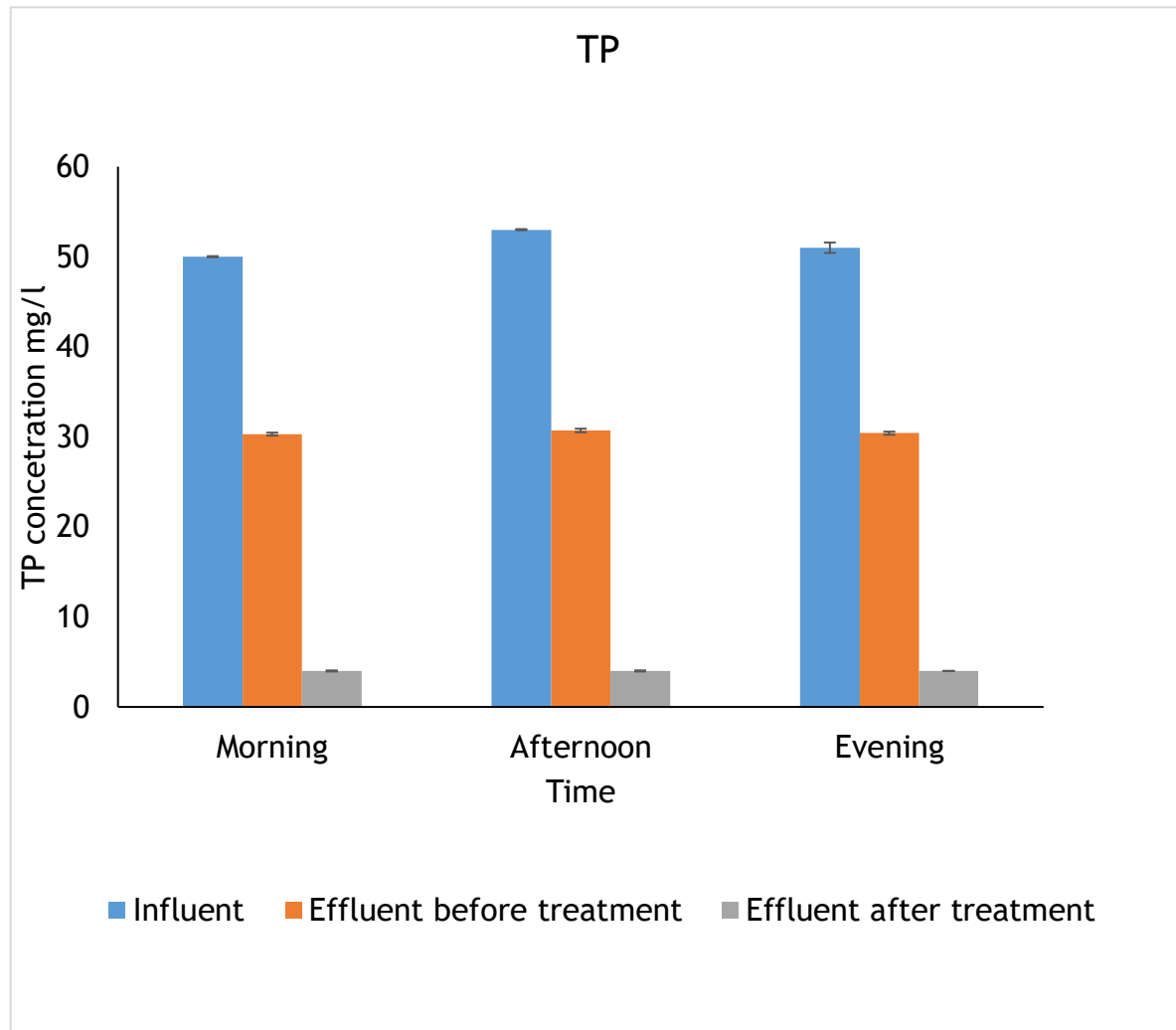


Figure 17: TP of wastewater effluent from maturation pond and influent of maturation pond as well as effluent after treatment.

Morning: The influent TP value was 50 ± 0.06 mg/l at the exit of the maturation pond, and it decreased to 30.3 ± 0.16 mg/l, indicating a 39.4% reduction in TP. The addition of alum extract demonstrated a high level of efficiency of 92%, and the final result was 4 ± 0.06 mg/l. The results indicated that the alum sludge extract was 86.8% more efficient than the maturation pond.

Afternoon: The influent was 53 ± 0.06 mg/l and decreased to 30.7 ± 0.20 mg/l at the

maturation pond's exit, indicating a 42.1% reduction in TP. The addition of alum extract demonstrated a high level of efficiency of 92.5%, and the final result was 4 ± 0.06 mg/l. The results indicated that the alum sludge extract was 87% more efficient than the maturation pond.

Evening: Influent was 51 ± 0.58 mg/l and it was reduced at the exit of the maturation pond to 30.4 ± 0.17 mg/l which showed an efficiency of 40.4% reduction of TP, addition of alum extract showed a high efficiency of 92.2%, and the final was 4 mg/l and alum sludge extract showed that it is 86.8% more efficient than the maturation pond. On average of three different samples, the maturation pond showed a TP percentage removal rate of 40.6%, while the alum sludge extract showed 92.2% and 86.9% more efficiency than the maturation pond.

This is the measure of phosphorus in wastewater, both dissolved and particulate. The addition of the alum dose to wastewater leads to the precipitation of phosphorus into Aluminium phosphate, which is insoluble and forms flocs that settle, reducing the total phosphorus discharged into the environment.

4.5.0 PROTOTYPE DESIGN AND ALUM EXTRACT REQUIRED TO DOSE

The design was informed by (Nozaic and Freese, 2009) design manual.

Retention time = volume/flow rate

Assuming retention time of 15 minutes

Flow rate = $10 / (10 * 60)$

Flow rate = 0.167 litre/sec



Figure 18: prototype.

Amount of alum sludge extract need to dose the prototype

35mg used to dose 0.001 m³

350mg to dose 0.01 m³

Amount of alum sludge extract needed to dose the Maturation Pond

Pond flow rate = volume/time

Note; According to National water sewerage corporation (NWSC) the discharge is 24499.98 m³/day.

$$Q = \frac{24499.98}{6 \text{ days}} = m^3/\text{day}$$

Amount of Alum sludge extract = **Q * Dose (optimum)**

$$= 4083.3 * 35 * 1000$$

Amount of alum extract= **142916550 mg/day**

Amount of sludge required per day

3g of dry alum sludge gives 98000mg of alum extract

142916550mg requires 4374.996g of dry alum sludge

Therefore, required alum sludge per day is 4.374kg

Volume of sulphuric acid required

3g was mixed in 100 ml of 3N sulphuric acid

4374.996g requires 145833.2 ml of 3N sulphuric acid

=145.833l of 3N sulphuric acid

To make 145.833 litres of 3N Sulphuric acid

1L required 82ml of 98% concentrated sulphuric acid

145.833L requires 11958.306ml

= 11.958L ≈ 12litres of 98% concentrated sulphuric acid is required per day

4.5.1 COST ANALYSIS

2.5 litre of sulphuric acid cost 55000ugx

1litre of sulphuric acid costs 22000ugx

12 litres of sulphuric acid cost 264000ugx

1 trip of 8tonnes(8000kg) truck transport for 17km =100,000ugx

8000kg transportation cost 100000ugx

4.39kg transportation cost 54.875ugx

Total cost =264054.875ugx/day

Dry alum sludge obtained from Surry alum sludge

4litres produced 1.25g

13999.89litres produce 4324.966g (4.324kg)

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The effluent discharged from Namatala wastewater stabilization ponds to the Namatala wetland is above the permissible limits, which had BOD of 192 mg/l > 50 mg/l, COD of 235.7 mg/l > 100 mg/l, TN of 50 mg/l > 10 mg/l, and TP of 30.5 mg/l > 10 mg/l. The highest percentage value of extracted Al was 15.81 mg/g of alum sludge at a solid loading of 5 g alum sludge/100 mL of H₂SO₄, and 3g of alum sludge/100 ml of H₂SO₄ the concentration, and for 10 g of alum sludge was 13.24% and 11.4% respectively. Alum extract that had an aluminium concentration of 13.24% was used in a jar test because it was more cost effective compared to other extracts, and it gave the optimum dosage of 3.5 ml/l at a pH of 7.78, and effectively reduced turbidity at a percentage of 82.3%. The extracted alum from the sludge was used in the prototype, and it effectively reduced BOD, COD, TP, and TN with efficiencies of 80%, 79.70%, 92.8%, and 87.6%, respectively.

5.2 RECOMMEDATIONS

- We recommend the use of alum sludge in the treatment of wastewater because it is cost effective and environmentally friendly.
- The different alum sludge composition should be analysed to understand how they affect the alum sludge extract, mostly negatively.
- The use of mixed alum and PAC sludge in the treatment of wastewater should be done.

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APPENDICES

Appendix 1



Figure 19: Dry Alum sludge



Figure 20: preparation of sulphuric acid 3N



Figure 21: Supernatant of alum extract in flasks.



Figure 22: Agitating machine.



Figure 23: Dissolved oxygen meter.



Figure 24: Testing and preparation of BOD samples.



Figure 25: BOD samples in the incubator.

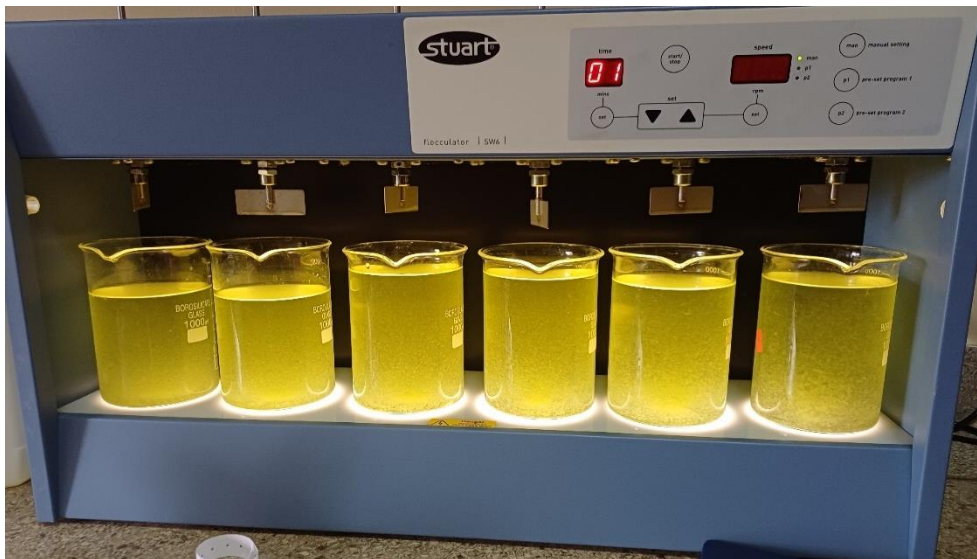


Figure 26: jar test machine with beakers filled with water samples.



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MINISTRY OF WATER AND ENVIRONMENT MBALE REGIONAL WATER QUALITY LABORATORY

Certificate of Analysis

Client Name : ALUNGAT SUZAN AND NUWABIINE YASIN
 Client Address : P.O Box , Kampala
 Sample type and condition : Wastewater Samples received in 1.l plastic bottle.
 Sample by : Client.
 Date Sampled : 23rd /11/2023
 Date received : 23rd /11/2023
 Analysis start date : 23rd /11/2023
 Analysis Completion date : 15th /12/2023

Ref No: MBL 24 -088

TEST RESULTS

Source Name	Units	Namatala Lagoon			Waste Water Discharge Standards
Village		Namatala			
Parish					
Sub county					
District		Mbale City			
Lab Identifier code		MBL 23/1257			
PH	Phunits	8.4	8.5	8.7	5.5-8.5
Turbidity	NTU	29.5	29.9	28.8	300
Electrical Conductivity	us/cm	778	777	778	<1500
Total dissolved solids	mg/l	544	546	546	
Biological Oxygen Demand	mg/l	193.6	192	193.9	<50
Chemical Oxygen Demand	mg/l	221	222	224	<100
Total suspended solids	mg/l	109	109	107	<100
Total Nitrogen-N	mg/l	51	49	51	10
Total Phosphate-P	mg/l	30.3	30.4	30.1	<10

- Note:
1. This certificate shall not be reproduced without approval of the Laboratory.
 2. **Test result from sub-contracted Laboratory
 3. Analysis site is Mbale Regional Water Quality Laboratory

Disclaimer

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**LABORATORIES
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**REGIONAL WATER QUALITY
LABORATORY - MBALE**

Issued by:

**PRINCIPAL ANALYSIS
LABORATORIES**

31 JAN 2024
**REGIONAL WATER QUALITY
LABORATORY - MBALE**
 Sign:.....

Ministry of Water and Environment,
 Mbale Regional Water Quality Laboratory
 Kyoga Water Management Zone
 P.O. BOX 1324, Mbale.



MINISTRY OF WATER AND ENVIRONMENT
MBALE REGIONAL WATER QUALITY LABORATORY
 Certificate of Analysis

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 Ref No: MBL 24 -088

TEST RESULTS

Source Name	Units	Namatala Lagoon			Waste Water Discharge Standards
		Namatala			
Village					
Parish					
Sub county					
District		Mbale City			
Lab Identifier code		MBL 23/1258			
pH	pH units	8.5	8.6	8.6	5.5-8.5
Turbidity	NTU	30.3	30.1	30.1	300
Electrical Conductivity	us/cm	777	777	777	<1500
Total dissolved solids	mg/l	545	545	543	-
Biological Oxygen Demand	mg/l	190.3	190.2	190.3	<50
Chemical Oxygen Demand	mg/l	252	251	247	<100
Total suspended solids	mg/l	107	107	106	<100
Total Nitrogen-N	mg/l	47	44	44	10
Total Phosphate-P	mg/l	30.5	30.7	30.9	<10

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**PRINCIPAL ANALYST
LABORATORIES**
Aluna
 ★ 31 JAN 2024 ★
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LABORATORY - MBALE**
 Sign:.....

Ministry of Water and Environment
 Mbale Regional Water Quality Laboratory
 Kyoga Water Management Zone
 P.O BOX 1324 Mbale
 Plot 14, Works Road Entebbe



**MINISTRY OF WATER AND ENVIRONMENT
MBALE REGIONAL WATER QUALITY LABORATORY**

Certificate of Analysis

Client Name : ALUNGAT SUZAN AND NUWABIINE YASIN
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 Sample type and condition : Wastewater Samples received in 1.l plastic bottle.
 Sample by : Client.
 Date Sampled : 23rd /11/2023 Analysis start date : 23rd /11/2023
 Date received : 23rd /11/2023 Analysis Completion date : 15th /12/2023

TEST RESULTS

Ref No: MBL 24 -089

Source Name	Units	Namatala Lagoon			Waste Water Discharge Standards
Village		Namatala			
Parish					
Sub county					
District		Mbale City			
Lab Identifier code		MBL 23/1259			
pH	pH units	8.7	8.6	8.6	5.5-8.5
Turbidity	NTU	29.3	29.1	29.3	300
Electrical Conductivity	us/cm	776	777	777	<1500
Total dissolved solids	mg/l	543.9	544	543.7	-
Biological Oxygen Demand	mg/l	192.7	192.5	192.7	<50
Chemical Oxygen Demand	mg/l	235	234	236	<100
Total suspended solids	mg/l	108	108	108	<100
Total Nitrogen-N	mg/l	53	55	53	10
Total Phosphate-P	mg/l	30.3	30.3	30.6	<10

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 3. Analysis site is Mbale Regional Water Quality Laboratory

Disclaimer

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- ◆ This certificate of analysis does not substitute certification of a business or product by other relevant authority.

Checked by:
**LABORATORIES
MANAGER**
 REGIONAL WATER QUALITY
 LABORATORY - MBALE

Issued by:
**PRINCIPAL ANALYST
LABORATORIES**
 ★ 31 JAN 2024 ★
 REGIONAL WATER QUALITY
 LABORATORY - MBALE

Ministry of Water and Environment
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Website: www.mia.go.ug

In any Correspondence on
this subject please
quote No. _____



MINISTRY OF INTERNAL AFFAIRS
DIRECTORATE OF GOVERNMENT
ANALYTICAL LABORATORY
Plot No. 2 Lourdel Road
Wandegeya,
P.O. BOX 2174
Kampala - Uganda

09/02/2024

ANALYSIS REPORT

Name of Client:	Alungat Susan and Nuwabiine Yassin
Address:	Uganda Christian University
Tel:	+256-703005763, +256744030722
Sample Submitted by:	Ms. Susan Alungat and Mr. Nuwabiine Yassin
Samples Submitted:	One sample of Sludge
Examination Request:	Aluminium

Test Results

The data contained within this test report was performed in accordance with the requirements of ISO/IEC 17025:2017. These results relate only to the test article listed in this report.

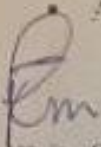
Aluminium analysis

The samples were analyzed using Atomic Absorption Spectrometer after extraction and digestion with microwave digester with the following results:

SAMPLE	TEST PARAMETER	RESULTS (mg/g)	
3g/100ml	Aluminium	Run1	405
		Run2	390
		Run3	397
5g/100ml	Aluminium	Run1	789
		Run2	801
		Run3	782
10g/100ml	Aluminium	Run1	1141
		Run2	1140
		Run3	1139

REMARKS

- The method detection Limit for Aluminium is 0.001 µg/L (ppb) based on the analytical method used.
- All results are reported on as received basis



Kizito Stanley
Laboratory Technician



Republic of Uganda

MINISTRY OF WATER AND ENVIRONMENT MBALE REGIONAL WATER QUALITY LABORATORY

Certificate of Analysis

Client Name : ALUNGAT SUZAN AND NUWABIINE YASIN, Uganda Christian University
 Client Address : Mukono
 Sample type and condition : Wastewater Samples received in 1.l plastic bottle.
 Sample by : Client.
 Date Sampled : 19/02/2024 Analysis start date : 19/02/2024
 Date received : 19/02/2024 Analysis Completion date : 19/02/2024

Ref No: MBL 24 -185

TEST RESULTS

RAW WATER PARAMETERS							
Temp(°C)		25					
PH		8.17					
colour (PtCO)		430					
Turbidity (NTU)		39					
Run No.	units	1	2	3	4	5	6
1% Alum Extract	ml	0.5	1	1.5	2	2.5	3
Alum extr Dose	mg/l	5	10	15	20	25	30
floc formation order	1-fastest to 6 slowest	4	2	6	1	3	5
floc size		Small	Small	medium	Big	Big	Big
settlement order	1-fastest to 6 slowest	6	4	5	3	2	1
scum formation	1-fastest to 6 slowest						
supernatant pH		8.15	8.13	8.08	8.12	8.05	7.95
supernatant Turbidity	NTU	18.6	16.7	12	12	10.6	8.6
supernatant colour	PtCO	400	380	360	340	340	320
Turbidity reduction %	%	52.31	57.18	69.23	69.23	72.82	77.95
colour reduction %	%	6.98	11.63	16.28	20.93	20.93	25.58
Run No.	units	7	8	9	10	11	12
1% Alum Extract	ml	3.5	4	4.5	5	5.5	6
Alum extr Dose	mg/l	35	40	45	50	55	60
floc formation order	1-fastest to 6 slowest						
floc size		Big	Big	Big	Big	Big	Big
settlement order	1-fastest to 6 slowest	1	3	2	5	6	4
scum formation	1-fastest to 6 slowest						
supernatant pH		7.78	7.75	7.69	7.68	7.63	7.57
supernatant Turbidity	NTU	6.9	6.4	6	6.5	6.2	4
supernatant colour	PtCO	290	275	260	235	210	215
Turbidity reduction %	%	82.31	83.59	84.62	83.33	84.10	89.74
colour reduction %	%	32.56	36.05	39.53	45.35	51.16	50.00

Optimum dose rate is demonstrated in Run No.....7.....ie.....3.5.....mg/l

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Checked by:

**LABORATORIES
MANAGER**

 12 MAR 2024
**REGIONAL WATER QUALITY
LABORATORY - MBALE**

Issued by:

**PRINCIPAL ANALYST
LABORATORIES**
 ★ 12 MAR 2024
**REGIONAL WATER QUALITY
LABORATORY - MBALE**
 Sign:.....

Ministry of Water and Environment
Mbale Regional Water Quality Laboratory
Kyoga Water Management Zone
P.O. BOX 1324, Mbale
Plot 14, Works Road Entebbe

MINISTRY OF WATER AND ENVIRONMENT
MBALE REGIONAL WATER QUALITY LABORATORY

Certificate of Analysis

Client Name : ALUNGAT SUZAN AND NUWABIINE YASIN

Client Address : P.O Box , Kampala

Sample type and condition : Wastewater Samples received in 1.1 plastic bottle.

Sample by : Client

Analysis Start date : 19/02/2024

Analysis Completion date : 11/03/2024

TEST RESULTS

Ref No: MBL 24 -183

Sampling Date	Parameter	Units	MBL24/244		MBL24/245		MBL24/246				
			Influent	Effluent	Influent	Effluent	Influent	Effluent			
19th/Feb/2024	Biochemical Oxygen Demand	mg/l	202	40.1	206	41	198.3	198.1	198.3	40.6	40.5
	Chemical Oxygen Demand	mg/l	395	80	401	83	397	397	397	79	79
	Total Phosphorous	mg/l	73	9.4	77	9.2	70	70	70.1	8.6	8.7
	Total Nitrogen	mg/l	50	3.6	53	4.1	51	52	51	3.5	3.5

Note: 1. This certificate shall not be reproduced without approval of the Laboratory

2. **Test result from sub-subsanctioned Laboratory (NATC) shall be considered as ISO 17025/15000

3. Analysis site is above Regional Water Quality Laboratory

4. (NIT - 700) Numerical To Error

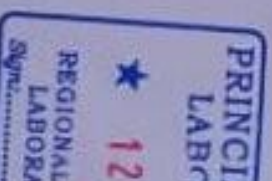
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 Kyoga Water Management Zone
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ANNEX

DETERMINATION OF TURBIDITY

Equipments used

- Beakers
- Nephelometric turbidimeter

Procedure

- Clean distilled water with a turbidity of zero was poured in a clean cell until the lower part of the meniscus is touching the reference line. The clean cell was then placed inside the Hach DR 900 machine. The outside of the cell was cleaned to remove any water droplets before placing it in the machine, and then placed into the designated slot on the machine and covered. This acts as a blank.
- Zero button on the machine was then pressed and the blank is removed.
- Raw water sample was placed in the clean cell in the machine and read button was pressed.
- The reading was then noted down in the table.
- The same procedure was repeated with other cells, while noting down the readings for each cell in the table.

DETERMINATION OF COLOR APHA 2120 C

Equipments used

- Colorimeter

Procedures

- Blank sample was prepared by obtaining a clean cell and poured in it a clear

volume of distilled water until the lower meniscus was at the mark on the bottle.

- The blank sample was placed into the equipment and the zero button was pressed. The blank was removed after getting a reading.
- The raw water sample was then poured into a new clean and dry and inserted into the machine and the read button was pressed. The result was recorded in the table.
- The procedure was then repeated two more times and each time, the readings were also recorded in the table

DETERMINATION OF ELECTRICAL CONDUCTIVITY APHA 2510 B

Conductivity, k , is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, and valence; and on the temperature of measurement. Solutions of most inorganic compounds are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly, if at all.

DETERMINATION OF TOTAL DISSOLVED SOLIDS APHA 2540 C

Total dissolved solids (TDS) are the portion of total solids in a water sample that passes through a filter with a nominal pore size of 2.0 μ m (or smaller) under specified conditions.

Principle

Filter a well-mixed sample through a standard glass-fiber filter. Then, transfer the filtrate to a pre-weighed dish, evaporate it to dryness, and dry it to constant weight in an oven at 180 °C. The increase compared to the empty pre weighed dish weight represents TDS.

Analysts can create a TDS standard as follows: Dry NaCl at 103-105 °C for 1 hr, weigh 0.05g, and dilute to 1 L with reagent water. This results in a 50-mg/L TDS standard.

DETERMINATION OF TOTAL SUSPENDED SOLIDS APHA (1975) METHOD 208D

Total suspended solids are a measure of the number of suspended solids in a water sample. Suspended solids are particles that are too large to dissolve in water, but are small enough to remain suspended in the water column. Gravimetric analysis is to be used to determine total suspended solids (TSS).

Principle

In this method, measured aliquots of a water sample are filtered through a pre-weighed glass fiber filter pad. These pads are placed into a 105 °C drying oven overnight to remove any remaining water. The pads are removed from the oven and placed into a desiccator to cool to room temperature. Once samples have reached room temperature, they are individually weighed on a four-place balance and their respective weights are recorded in a spreadsheet and the concentration is reported as mg/L total suspended solids. If samples are to be used to determine total volatile solids, they are placed into a numbered porcelain crucible and dried in a muffle furnace at 550 °C for 1.5 hours. The samples are placed into a desiccator to cool to

room temperature. Once they have cooled, they are weighed on the four-place balance and their weights are recorded.

Procedure

- The sample was shaken vigorously so as to attain a complete mixture.
- 25ml of distilled water was added for the blank sample and 25ml of samples were added in different cells.
- The spectrometer was zeroed with the blank sample and the concentration in mg/l of the sample was read.
- Wavelength was 630nm.
- The reading from the machine were directly recorded.
- Read the concentration of the samples and recovered reading in the work form.
- Calculation.

$$\text{Original TSS units} = \frac{(v_s + v_w)(\text{instrument reading})}{v_s}$$

Where;

V_s : volume of sample

V_w ; volume of dilution water

DETERMINATION OF TOTAL PHOSPHATES (ASCORBIC METHOD)

Reagent;

- Sulphuric acid
- Potassium antimonyl tartrate solution.
- Stock phosphate solution

- Ascorbic acid

Apparatus

- Spectrometer CECIL 1000, reading at 880nm
- Acid-washed glassware

Procedure

- 25ml of diluted or whole filtered sample was taken, and not exceeding a p content of 15 µg/l into a 50ml stoppered volumetric flask.
- A blank was prepared and phosphate standard by taking 25ml of known standard concentration. both blank sample and phosphate standard were treated in the same way as the sample.
- The samples were heated in an autoclave at 120^oc and the temperature is maintained for 30 minutes and then allowed to cool to room temperature is maintained for 30 minutes and then allowed to cool to room temperature.
- The color reaction was made in the destruction bottles. Added 3ml of combined reagent and shook to mix.
- Finally added 1ml of ascorbic acid to each sample and was shoke and allowed to stand for 20 minutes for blue color development.
- Measured the concentration in mg/l at 880mm wavelength using the spectrometer CECIL 1000 series and values were read and recorded the results.
- Multiplied the reading by the dilution factor where applicable to obtain the concentration of TP in the sample in mg/l.

DETERMINATION OF TOTAL NITROGEN(KJELDAHL DIGESTION METHOD)

Reagents

- Selenium powder
- Sulphuric acid
- Lithium sulphate
- Ethanol
- Ammonium sulphate
- Potassium sulphate
- Copper sulphate
- Methyl red indicator
- Thymol blue indicator
- Sodium hydroxide
- Boric acid
- Hydrochloric acid
- Bromocresol green indicator

Procedure

1. The sample amount was measured in dry and clean digestion flask and 300ml were diluted with ammonia free water and a few chips of boiling stones.
2. 20ml of digestion mixture were added until the solution in the digestion flask was colorless, transparent and pale green. The content was allowed to cool and 100 to 200ml of ammonia free distilled water was added depending on the volume of the liquid in the digestion flask.

3. A steam distillation apparatus was set up and the sample solution was transferred to the reaction chamber and 25-50ml of 40% NaOH was added and steam distilled immediately.
4. Into 25mls of 1% boric acid containing 4 to 5 drops of mixed indicators. Distillation was continued until all the ammonia was distilled off and the indicator run green, the distillate was then removed and titrated with N/70 HCL depending on the amount of ammonia present in the sample, the end point being reached when the indicator changes from grey to pink. The ml of the standard HCL required was noted.
5. A blank determination was run by digesting reagent blanks in place of the sample and distilling as above and titrating with N/70 HCL. The ml of N/70 required of the blank usually 0.05 was subtracted from the burette reading from the sample titration.

Calculation

Mg/1N in the sample = (corrected ml of N) / (q70 HCL *100*1.0ml of sample)

BIOCHEMICAL OXYGEN DEMAND (BOD)

BOD is a measure of the amount of oxygen consumed by microorganisms as they decompose organic matter in water. BOD is expressed in milligrams of oxygen consumed per litre of water over a specified period of time. Using azide modification of Winkler method (oxygen electrode method). Biochemical oxygen demand is a measure of the amount of oxygen consumed by biochemical degradation of organic matter, inorganic materials present in wastewater over a specified incubation period usually 5 or 7 days.

Principle

The method applied involves filling an airtight bottle of a precise specified volume to overflowing with a sample and incubating at a specified temperature, usually, 20°C for 5 or 7 days.

Interference

Plus tard

Equipments used

1. Incubation bottles of 300ml.
2. An air incubator with controlled temperature at $20 \pm 1^\circ\text{C}$.
3. A 10ml pipette with aspirator.
4. Water tray with a capacity to contain small volume of water to be used as water seal by inverting the filled incubation bottles.
5. Oxygen meters with probes able to freely enter and rotate into incubation bottles.

Reagents

- Ferric chloride solution
- Magnesium sulphate
- Phosphate buffer solution
- Calcium chloride solution

Procedure

1. Preparation of dilution water.

Transfer a desired volume of water into a suitable container. Saturate the water with dissolved oxygen by shaking or aerating with organic free filtered air.

2. Preparation and measurement of initial Dissolved oxygen

Add a known volume of a sample to the individual BOD bottles of 300ml. fill the bottles up to the brim with enough diluted water so that the stopper is inserted, and air is displaced leaving no bubbles. When using titrimetric method for DO measurement, prepare two bottles for each dilution, determine initial DO in one bottle and put the stopper tightly, water seal and incubate for 5 days at 20^oc. The electrode has to be rinsed with distilled water after each measurement to avoid cross contamination of samples and the tests are carried out starting from the less concentrated sample to the more concentrated sample to the more concentrated one.

3. Preparation of blank sample

A blank sample is prepared in order to work as a calibrator of the DO machine. This sample container is filled with diluted water.

4. Incubation.

All the bottles were checked to ensure that they are all sealed before put in the incubator for incubation.

5. Determination of the final BOD after 5 days of incubation.

Formula

$$BOD \text{ }^{mg}/l = (DO_1 - DO_5) * DF^{9DOO}$$

CHEMICAL OXYGEN DEMAND (REFLUX METHOD)

Chemical oxygen demand is a measure of the amount of oxygen required to oxidize all oxidizable organic matter in a water sample. This test provides a quantitative measure of the total amount of pollutants available in the water, this includes both organic and inorganic compounds. High levels of COD in effluent indicates the

presence of pollutants that can have can be harmful to human beings and environment such as phosphorous and nitrogen compounds that can cause eutrophication of water bodies.

The COD is tested by closed reflux method.

General

The COD determines the amount of oxygen required for oxidation of organic matter using a strong chemical oxidant such as potassium dichromate under reflux conditions.

The test is widely used to determine the same type of pollutant as the biochemical oxygen demand.

Principle

Most types of organic matter oxidized by boiling mixture of chronic sulphuric acids. A sample is refluxed in strongly acid solution with a known excess of potassium dichromate. The amount of potassium dichromate consumed is proportional (1:7) to the oxygen required to oxidize the oxidizable matter. Normally, a sample of 50milliliters volume is used

; however, when other volumes are used, keep ratios of reagent, strength constant and volumes. The standard two hours reflux time may be reduced if it has been that shorter period yields the same results.

Reagents

Procedure.

- ✓ The digestion tube and caps are washed with distilled water before use to prevent contamination.
- ✓ 2ml of distilled water is put in one tube for the blank sample and 2ml of each

sample in different tubes.

- ✓ 2ml of the digestion solution is the added to each tube.
- ✓ Carefully 2ml of sulfuric acid is run down inside of the tube so an acid layer is formed under the sample.
- ✓ Tightly closed tubes and swirl several times to mix completely without inverting the tubes.
- ✓ The tubes were placed in a preheated oven of 150 °C during 2 hours.
- ✓ Allowed them to mix the content and let particles settle.
- ✓ The next day, transferred the content gently without mixing to a 1cm tube and measure the concentration at 620nm against blank.
- ✓ Read the concentration of the samples and recover reading in the work form.
- ✓ Calculation

$$\text{COD as } mg O_2 = \frac{mg O_2 \text{ final volume} \times 1000ml}{mL \text{ sample}}$$

JAR TEST

Apparatus used

- Six glass beakers of 1 liter capacity each
- Floc tester
- Conical flask
- Turbid meter
- Measuring cylinders
- Syringes

Reagents

- Extracted alum solution
- Distilled water

Procedure

- 1000ml of raw water is measured into of the six jars and then placed on a floc tester and all beakers were labeled with a permanent marker with number 1-6 depending on their respective dosages.
- Alum extract solution was varied in concentration from weak to strong and put in syringes
- The floe tester was then switched on and the stirrers lowered accordingly into each glass jar making sure they do not touch the sides or bottom of the glass jar.
- Quickly, the prepared dosages were added to the six glass jars containing the raw water and rapid mixing was set at 250 revolution per minute for 2 minutes, followed by slow mixing at 30 revolutions per minute for 15 minutes.
- After 30 minutes, the floc tester was stopped, stirrer pulled up out of the glass jars and observed and noted the sequence of floc settlement in the sequence of floc settlement in the sequence of the jars.
- After an hour, the conical flasks were used to gently decant off 250ml of the sample that was used to test for supernatant turbidity, pH and others.
- The results obtained were a guide in the selection of the optimum dosage for particular quality of water under experiment.

Note: Laboratory Analysts performed all the analysis as per each method above. It is the responsibility of the Laboratory Analyst to ensure that all conditions laid down in the method are met and strictly adhered to. Any deviations from the prescribed method were recorded and supervisor notified.